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NAVAL UNDERWATER SYSTEMS CENTER
NEW LONDON LABORATORY
NEW LONDON, CONNECTICUT 06320

Technical Memorandum

A COMPARISON OF MULTIPATH ARRIVAL STRUCTURES OBSERVED IN THE PRESENCE OF A SURFACE DUCT WITH PREDICTIONS OBTAINED USING CLASSICAL RAY TECHNIQUES AND THE PARABOLIC EQUATION METHOD

14 February 1985

Prepared by: Herbert A. Freese
Herbert A. Freese
Advanced Systems Concepts
Submarine Sonar Department

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

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ABSTRACT

Observed underwater acoustic multipath arrival structures are compared with theoretical predictions based on historic sound speed profiles for the vicinity of the Mid-Atlantic Ridge (3500 m water) and the Blake Plateau (1000 m water). Examining these comparisons for surface duct environmental conditions resulted in the conclusion that wave theory is necessary for predicting the distribution of received energy and that classical ray theory (i.e., ray propagation using the high frquency assumption without sound leakage correction) is inadequate.

ADMINISTRATIVE INFORMATION

This technical memorandum was originally prepared under Project No. A62000, 'Acoustic Communications for Submarines and Surface Vessels,' Principal Investigator, A. W. Ellinthorpe. The sponsoring activity was the Naval Sea Systems Command, NAVSEA 63DB, D. M. Early, Program Manager. The memorandum is being issued under Project No. A65000, 'Environmental Acoustic Support for Shipboard Sonar', Principal Investigator, B. F. Cole. The sponsoring activity is the Naval Sea Systems Command, NAVSEA 63R1, D. E. Porter, Program Manager.

When this memorandum was originally prepared (14 May 1981) the author was located at the New London Laboratory, Naval Underwater Systems Center, New London, Connecticut 06320. The author is presently located at Arete Associates, Arlington, Virginia 22202.

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INTRODUCTION

Observations of multipath arrival structures made at sea using short pulses have indicated that energy leaking into and out of surface ducts can play a significant role in the propagation of acoustic energy. This leakage phemomenon was first reported over twenty years ago by W. Thorpe and others with reference to leakage into and out of refracted-surface reflected (RSR) paths. Recent experience has indicated that this leakage phenomenon can also be of importance for energy propagating via bottom bounce modes.

This leakage phenomenon will be quite general, since surface ducts exist for a good portion of the year in many regions of the world's oceans. In fact, Thorpe et al., also demonstrated that the surface duct need only be present over some part of the total range in order for the leaky arrivals to exist. The particular leakage mechanism which is referred to is shown pictorially in Figure 1. Simply stated it is tunnelling through a potential barrier, an effect which diminishes with increasing frequency and with increasing distance of the source/receiver from the duct boundary. This does not imply that the effect is important only at low frequencies; first, depending on the particular source/receiver geometry and the duct shape, this effect could have an impact on current and future operational sonars, and second, scattering into and out of the duct by internal/surface wave action may enhance the effect.

This phenomenon leads to the characteristic arrival pattern shown in Figure 2. The salient aspects of this arrival structure are a set of equally spaced early arrivals followed by arrivals with rapidly decreasing increasing with range. If classical ray techniques are used in an attempt to predict the arrival structure the earlier equally spaced arrivals will be missing. On the other hand, solutions which account for the wave nature of the acoustic field will be successful.

The purpose of this memorandum is to compare observed multipath arrival structures with those predicted using ray theory (CONGRATS I) and wave theory (parabolic equation (PE)) and to indicate the superiority of the latter under the conditons stated herein.

DISCUSSION

We wish to examine a set of multipath arrival structures obtained in the vicinity of the Mid-Atlantic Ridge (3500 m water) and the Blake Plateau (1000 m water). These data sets are of interest because it was suspected that leakage into and out of a surface duct and into bottom bounce paths played an important role in determining the arrival structure.

Several examples which illustrate the nature of the multipath structure are shown in Figures 3 through 6. These data, which are a subset of those to be used in this memorandum, were obtained at 500 and 1600 Hz using 10 msec Gaussian pulses (Blake) and at 750 Hz using 20 msec Gaussian pulses (Mid-Atlantic Ridge). In all cases shown, the arrival structure usually represents an average of the received intensity over thousands of received pulses. Note also that the time scales on these plots is not the same for each case.

We will proceed by using historical sound velocity profiles obtained from reference (a) as inputs to a ray program (CONGRATS I) and a wave program (PE), profiles which are appropriate for the area in which the data were taken. For the PE simulation we will use the program described in reference (b) to propagate pulses whose duration is short enough to resolve the individual paths. A comparison between the two theoretical techniques (at 500 Hz) and the observations will then be made with particular attention being payed to the relative path arrival times. In each case the water depth will be chosen to match the average water depth in the experimental areas.

The first data set which we will examine are those obtained in the vicinity of the mid-Atlantic Ridge during the month of November. The results of the PE and CONGRATS runs for a water depth of 3500 meters are shown in Appendix A. The arrival time data are summarized in Figures 7 through 10 using a water depth appropriate for the experimental area. We have identified each path on these figures using the following terminology: DS indicates a surface duct path, Bn indicates a bottom bounce path interacting with the bottom n times, and a subscript 1 is attached to a path if it is generated by energy leaking through the duct. The ray theory results are always referenced to an imaginary straight line ray traveling in the duct. As can be observed from this set of data the agreement between the observed arrival times and PE technique is quite good. As expected the ray theory quite generally fails to predict the earlier, leaky arrivals.

The second data set which we wish to examine was obtained in the month of February in the vicinity of the Blake Plateau. The results of the CONGRATS I and PE run are summarized in Appendix B using a water depth of 900 meters. The arrival time data is summarized in Figure 11 using the appropriate water depth. Again, the ray theory results are referenced to an imaginary ducted ray. Note that the PE technique predicts the arrival structure quite nicely while the ray technique does not predict the earlier arrivals.

The last data set was also obtained in the vicinity of the Mid-Atlantic Ridge, but this time during the month of March. The CONGRATS I and PE runs for this time of year and area are shown in Appendix C for a water depth of 3500 meters. The arrival time data is summarized in Figures 12 and 13 using the appropriate water depth. The agreement between the PE technique and the observations on the first data set are good out to about 37.5 nautical miles but then the agreement is no longer good, perhaps because of scattering in the surface duct and/or a change in the sound speed profile in the vicinity of the duct. The results for the second data set show a good agreement between the PE method out to 117 nautical miles but the ray technique again fails once the leaky modes can be excited.

CONCLUSIONS

Being able to understand this leakage phenomenon and to calculate its effect on the received signal energy is important for a number of reasons. First the existence of energy which can leak into and out of a surface duct (or any duct for that matter) is certainly important for establishing a physical understanding of the propagation physics. The matter of proper path identification falls into this category. This is true regardless of whether the energy leaks into bottom bounce modes or RSR modes. A second, an even more important reason for accounting for this phenomenon carefully is its possible impact on operational systems and algorithms. For example, the effect of this mechanism on sonar systems and system design could be significant. This is particularly true if one considers that under certain circumstances, these leaky paths contain a significant portion of the received energy.

Another conclusion which one can draw from these comparisons is that one is well advised to avoid standard ray techniques such as CONGRATS and FACT for example, when it is suspected that leakage may be important. Techniques such as RAYMODE should also be avoided in these instances because, although RAYMODE accounts for leakage out of the duct it does not allow for leakage back into the duct. This is true even though the technique on which it is based (multipath expansion) is quite general and includes wave effects. In this regard, H. Weinberg has implemented a program based on the multipath expansion technique which offers the promise of a proper accounting of all the propagating energy. A comparison of multipath arrival patterns computed using Weinberg's technique, will be made with our observations in a subsequent memorandum.

Finally, full wave techniques such as PE, FFP, and normal modes, account properly for the received energy. They however generally suffer from a burden of requiring excessive computer time in order to make the necessary computations.

REFERENCES

(a) E. Podezwa, "Sound Speed Profiles for the North Atlantic Ocean", NUSC Technical Document 5447

(b) H. Freese and P. Maciejewski, "Solution of the Parabolic Wave Equation Implemented on a Floating Point Systems Array Processor", NUSC Technical Memorandum No. 811062

LEAKAGE MECHANISM

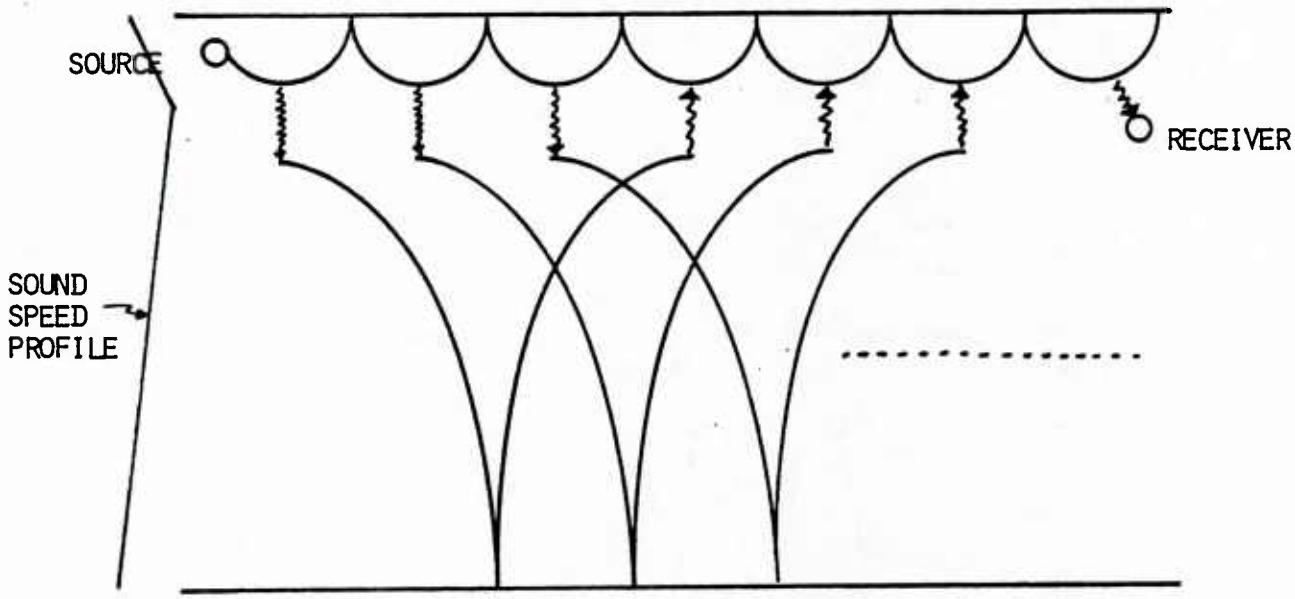

FIGURE 1. ILLUSTRATION OF LEAKAGE PHENOMENON

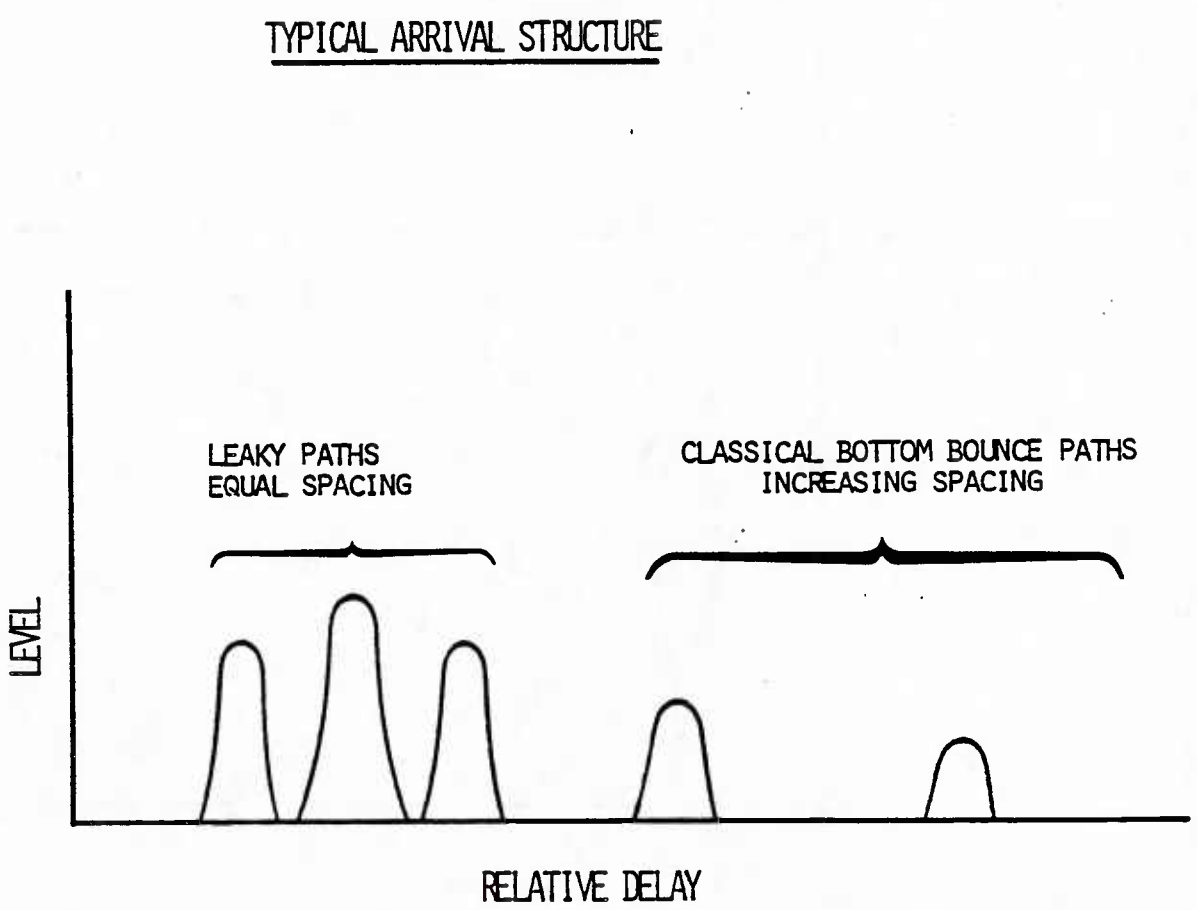

FIGURE 2. TYPICAL ARRIVAL STRUCTURE

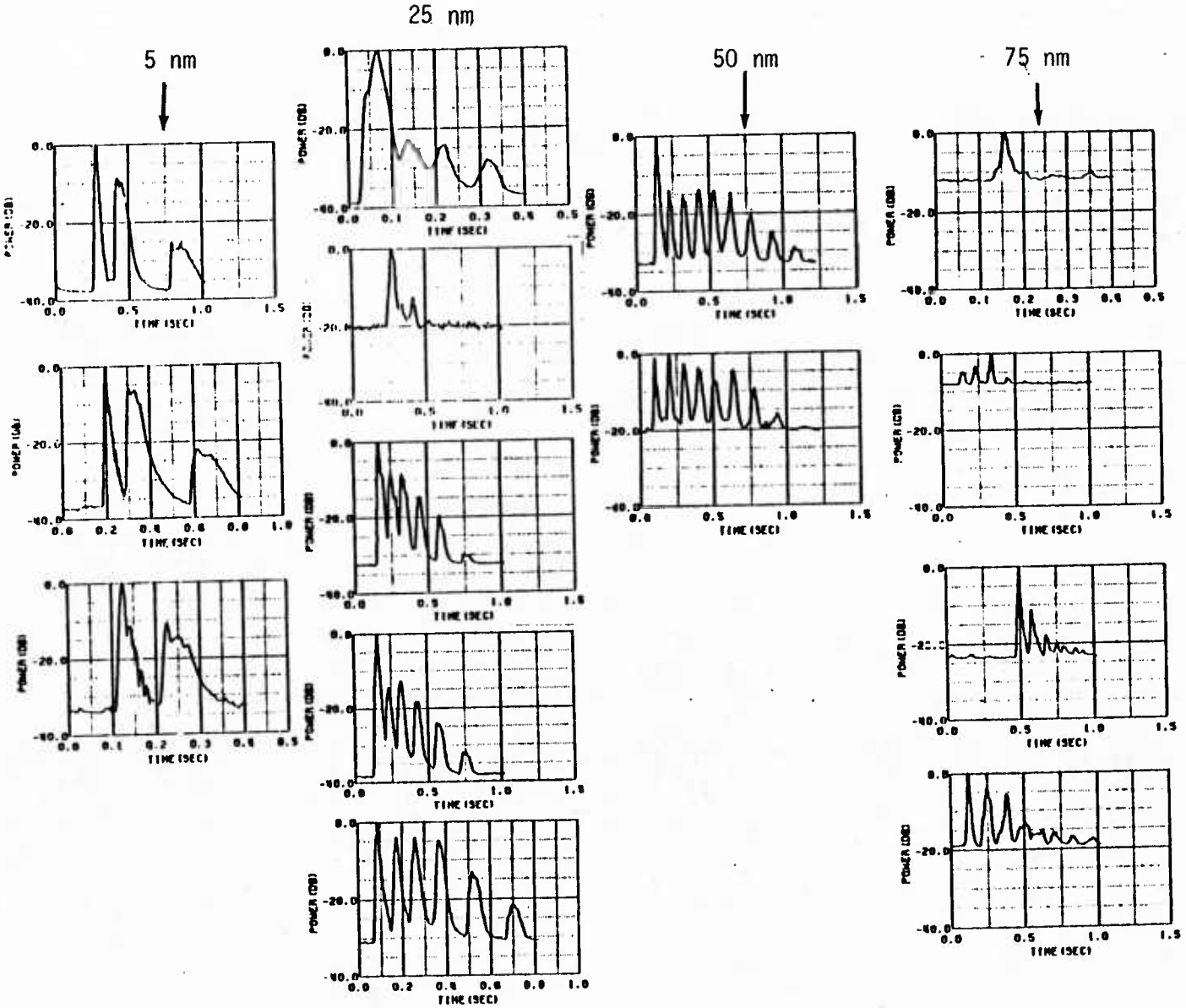

FIGURE 3. BLAKE DATA, 500 HZ, JANUARY

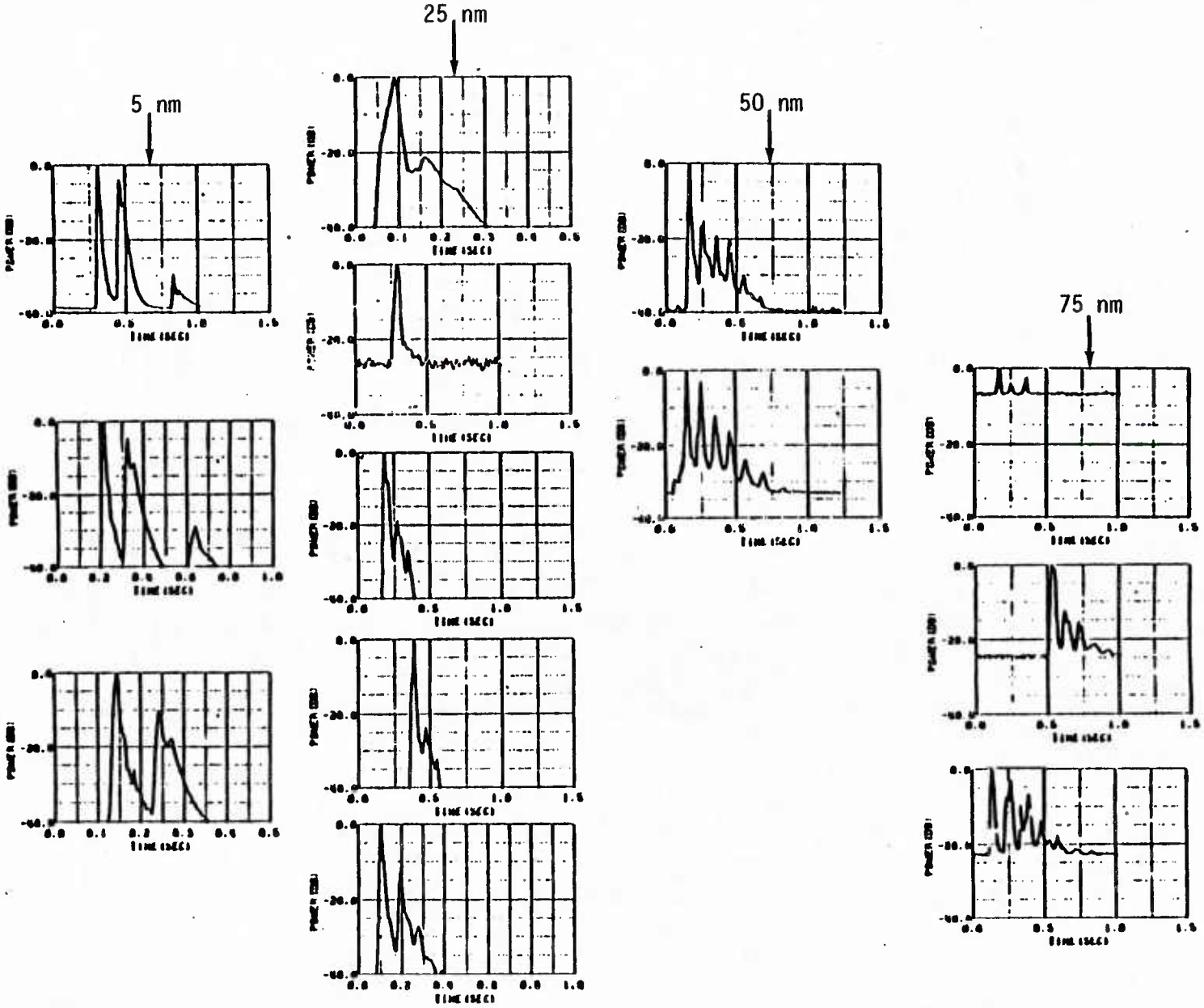

FIGURE 4 BLAKE DATA, 1600 HZ, JANUARY

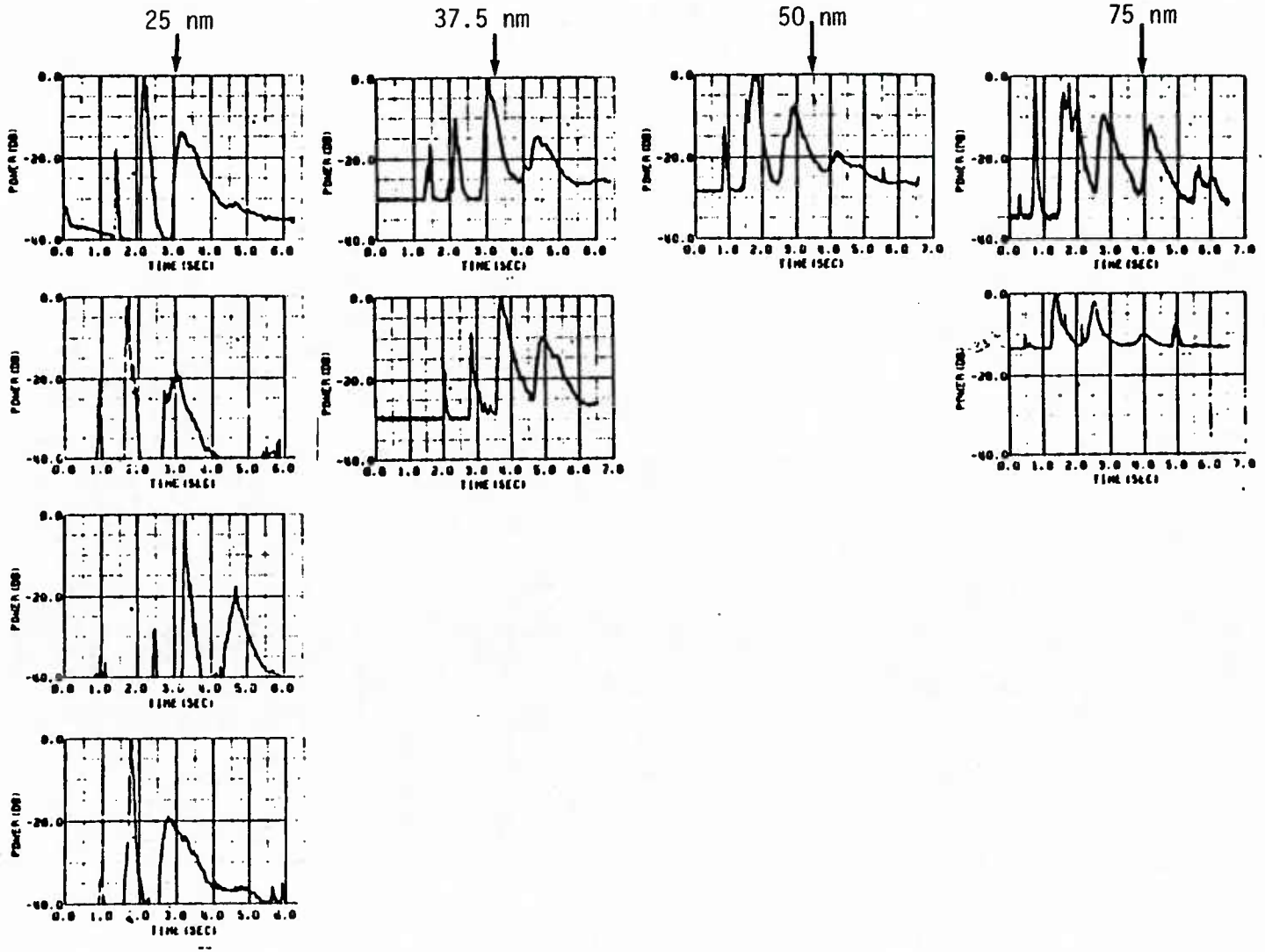

FIGURE 5 RIDGE DATA # 1, 750 HZ, MARCH

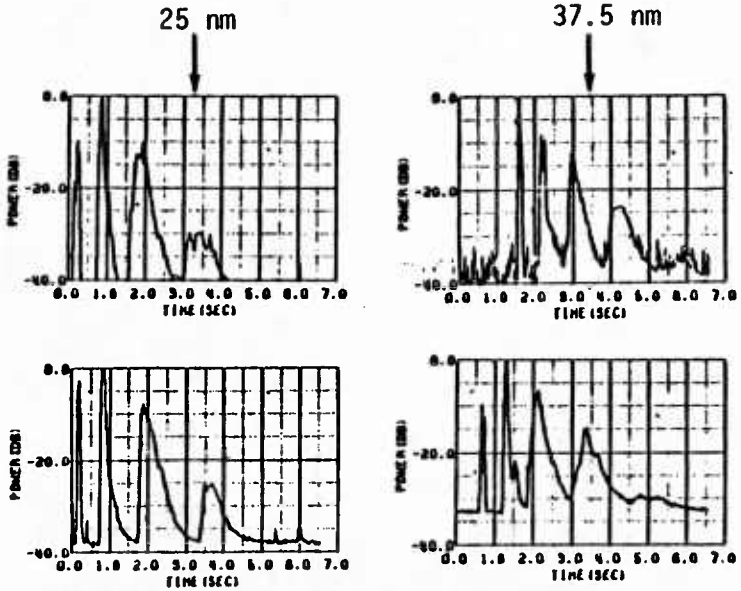

FIGURE 6 RIDGE DATA # 2, 750 HZ, MARCH

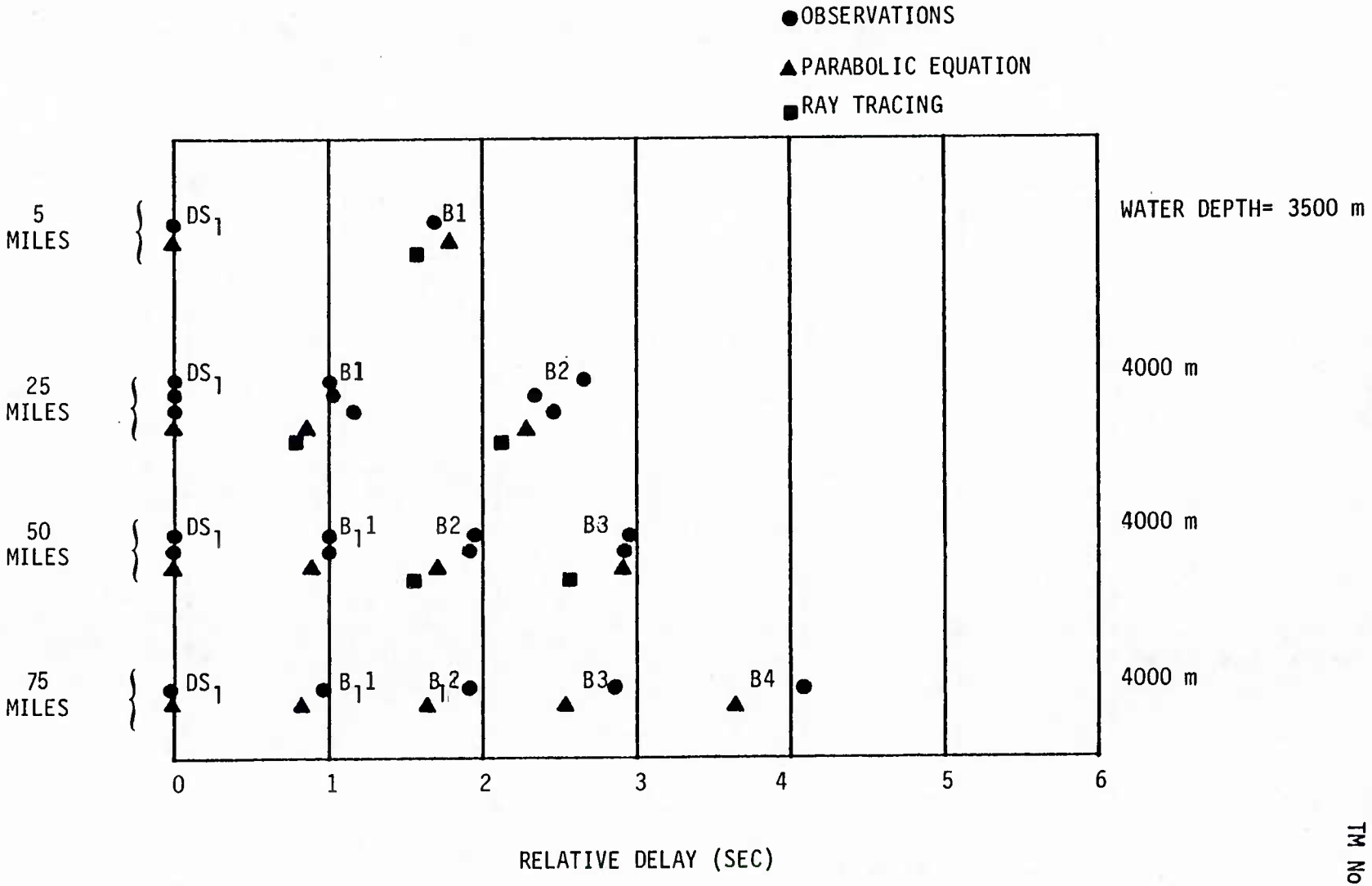

FIGURE 7 RELATIVE ARRIVAL TIME, MID-ATLANTIC RIDGE # 1 NOVEMBER

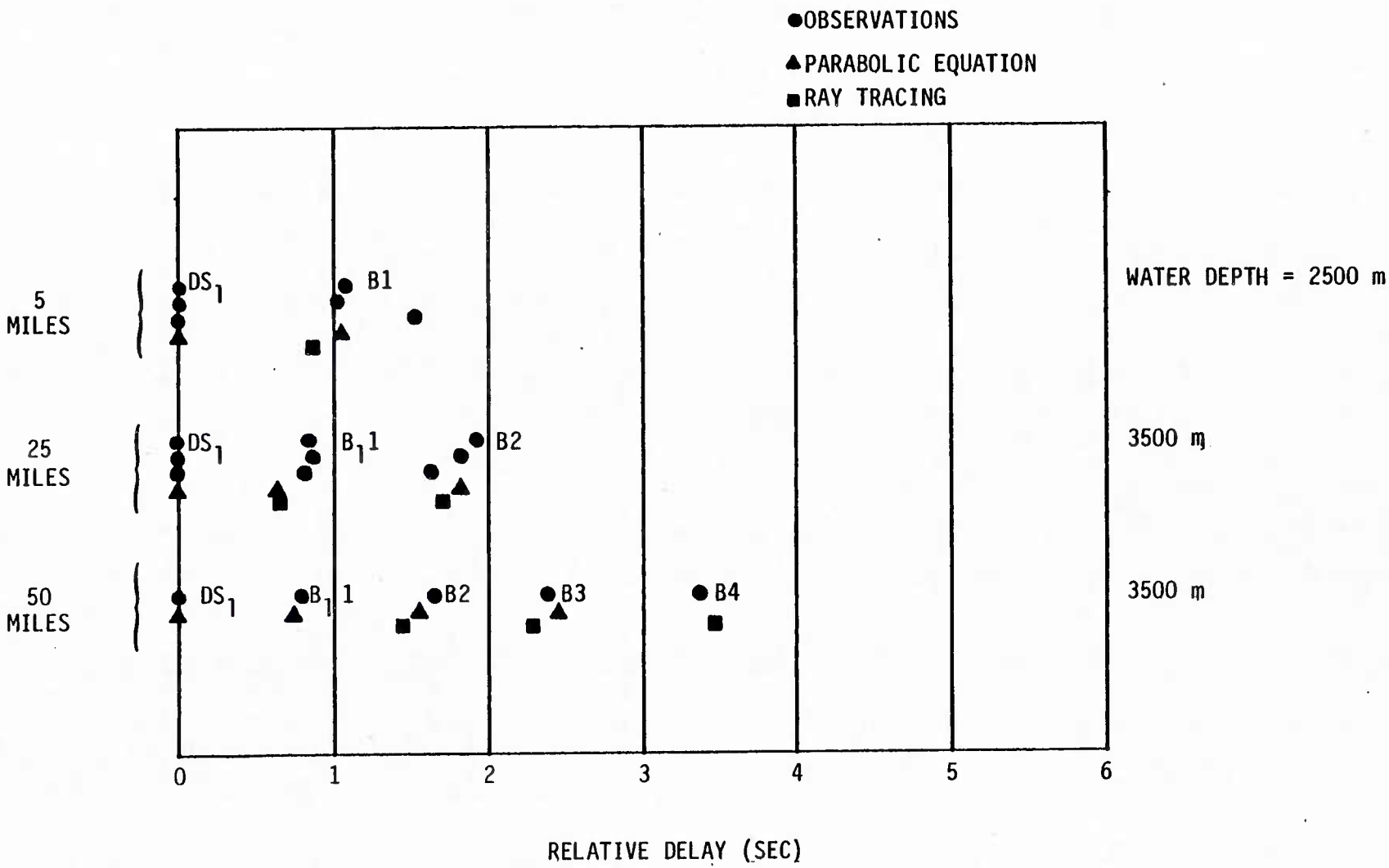

FIGURE 8 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 2 NOVEMBER

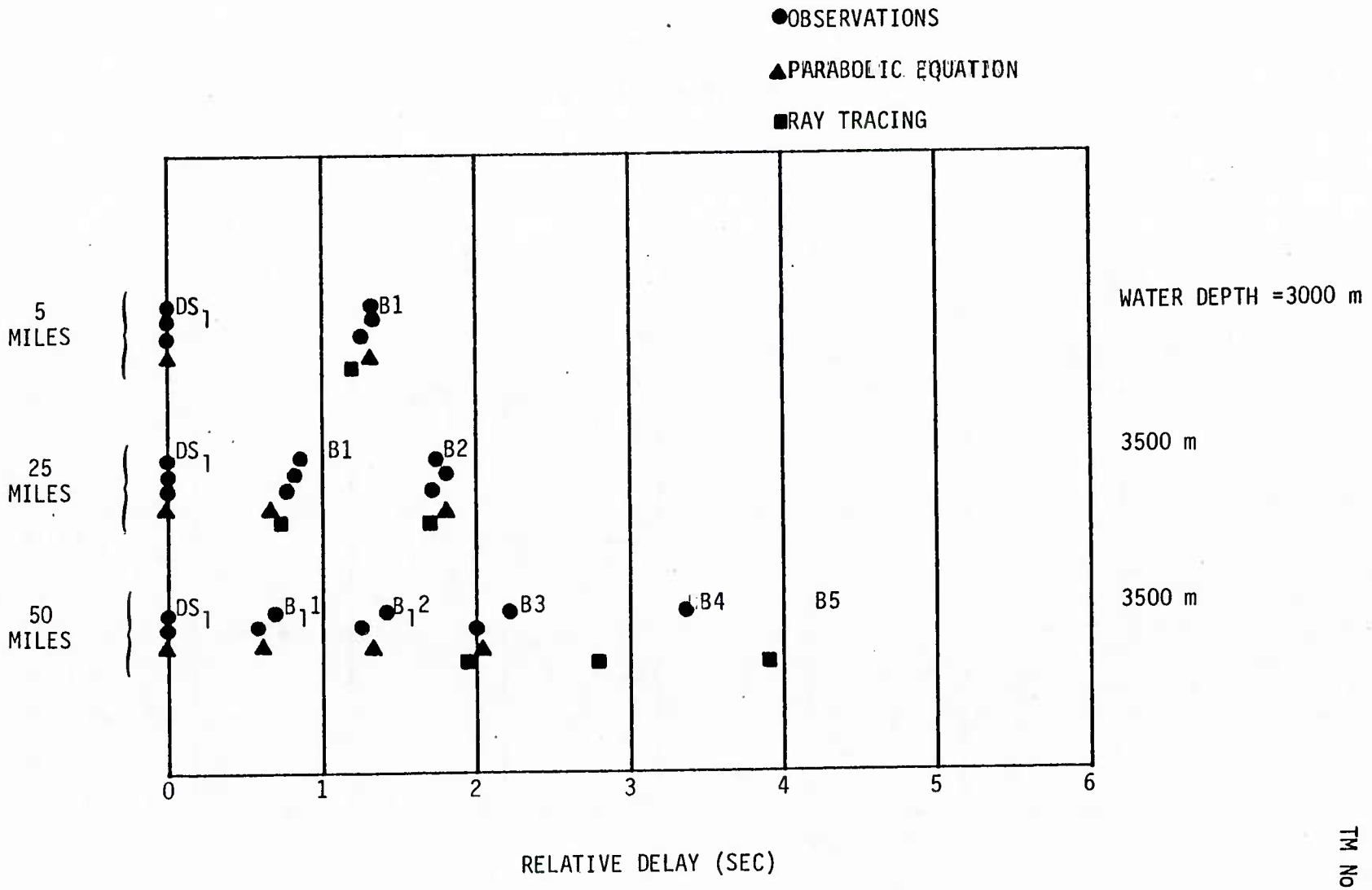

FIGURE 9 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 3 NOVEMBER

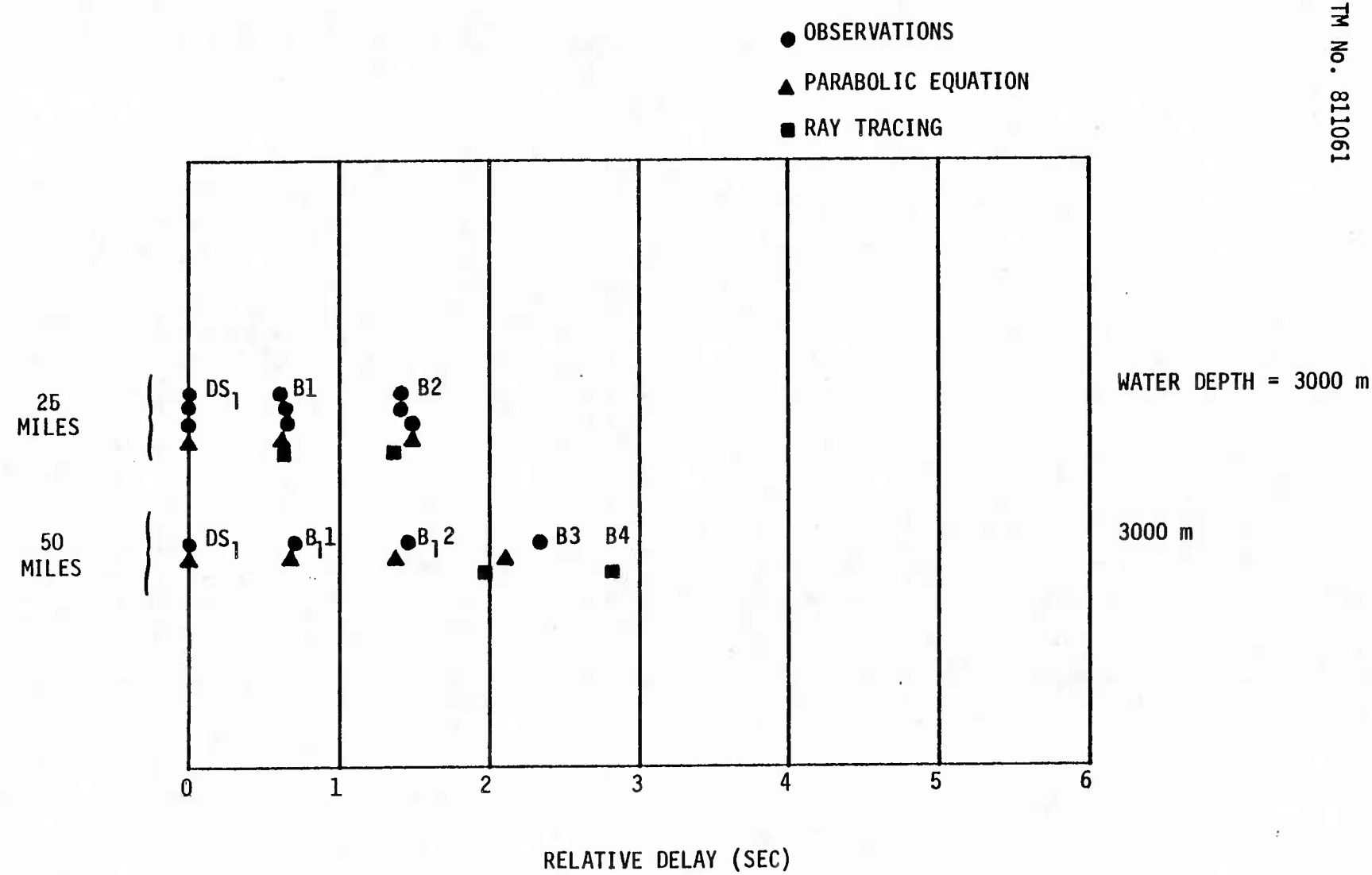

FIGURE 10 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 4 NOVEMBER

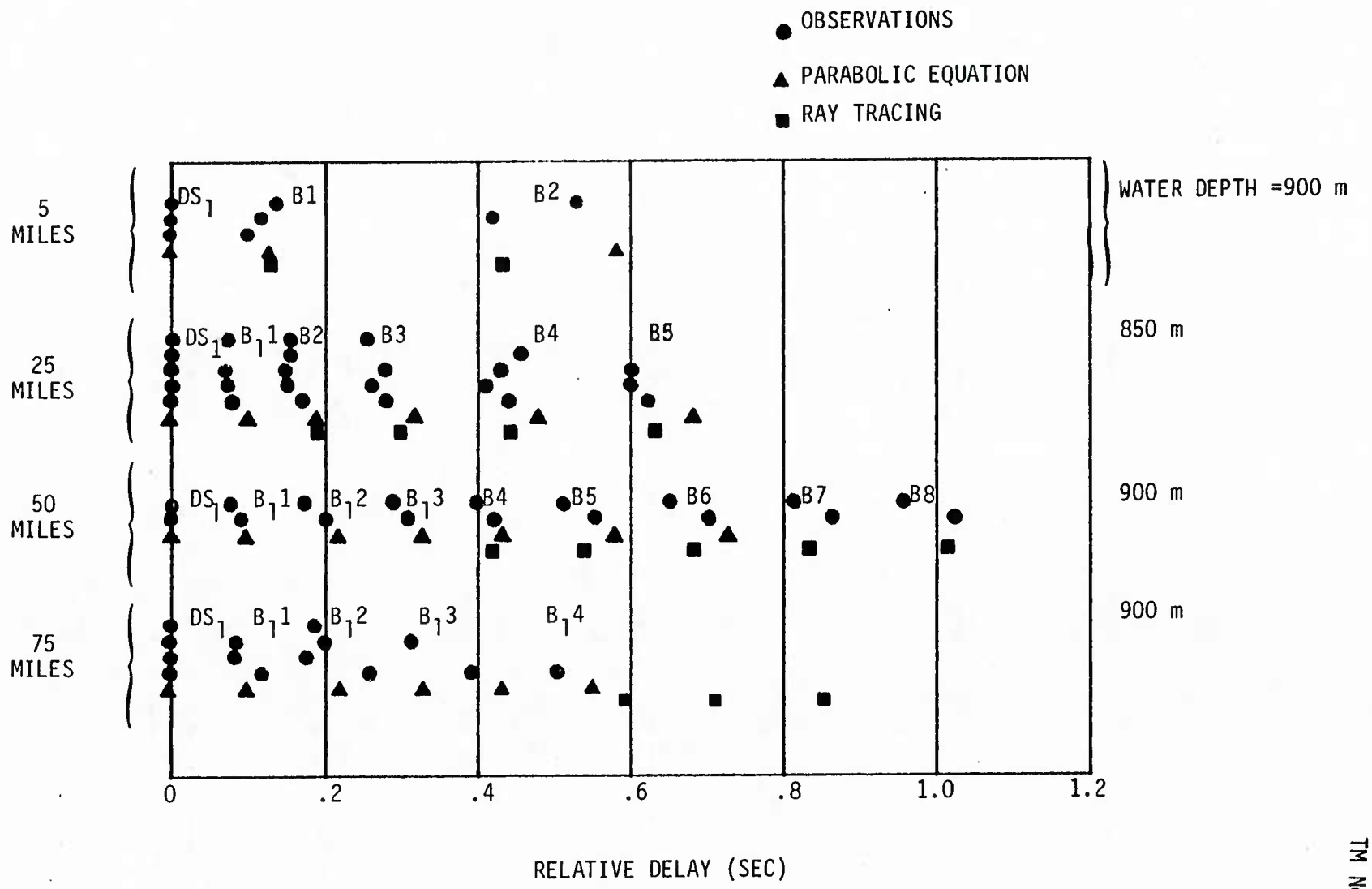

FIGURE 11. RELATIVE ARRIVAL TIMES, BLAKE PLATEAU JANUARY

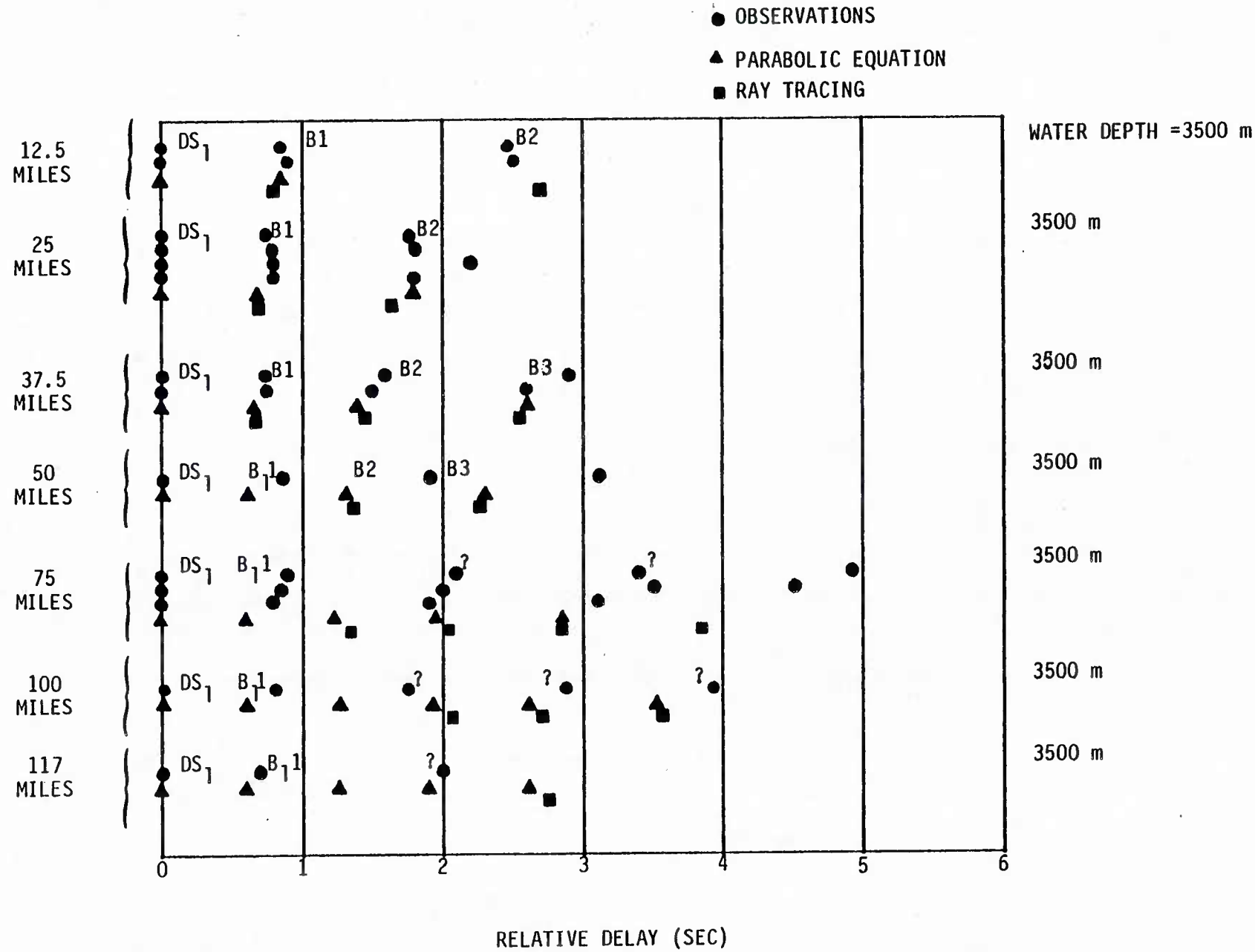

FIGURE 12 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 1 MARCH

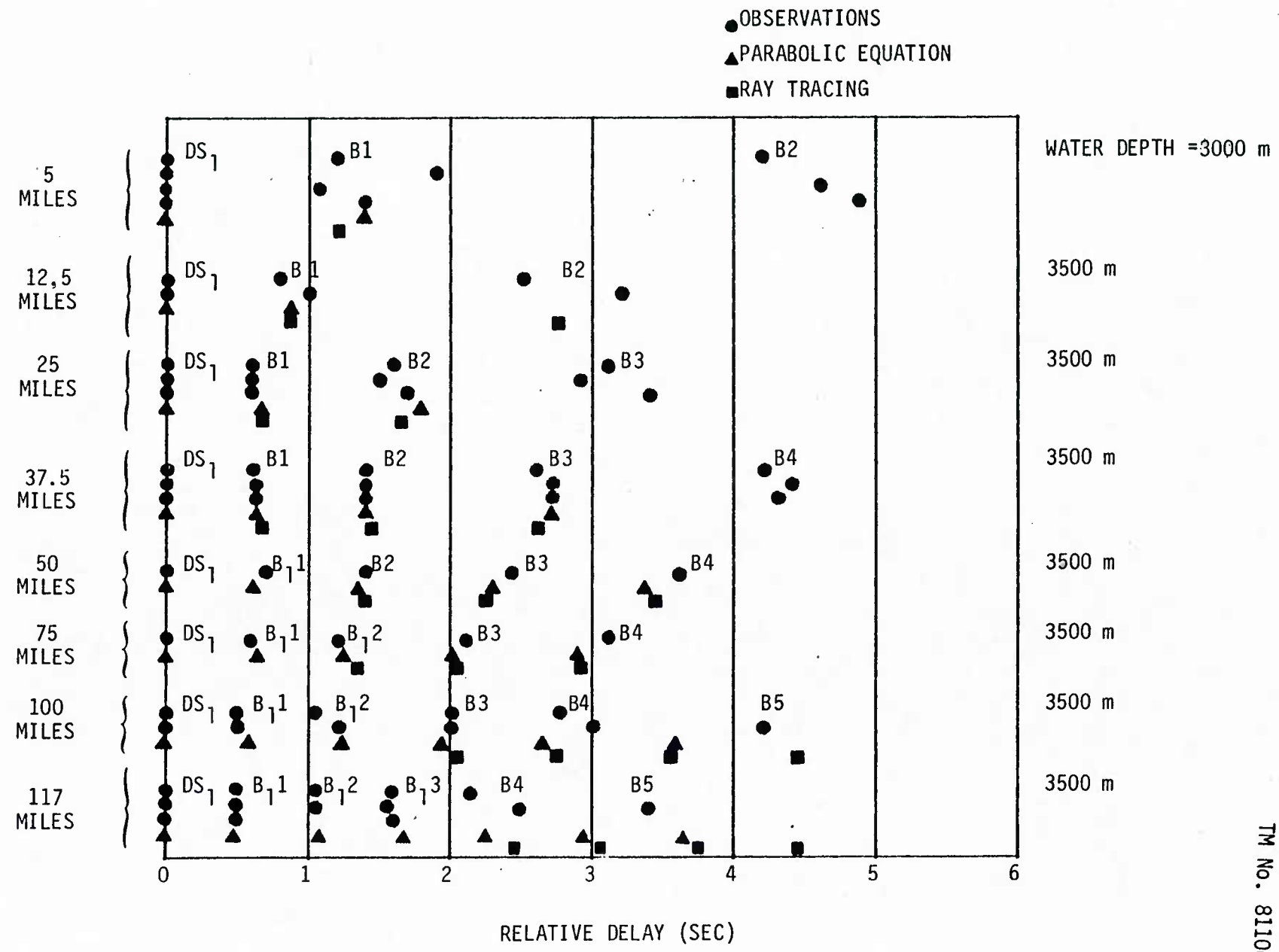

FIGURE 13 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 2 MARCH

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APPENDIX A

MID-ATLANTIC RIDGE PE & RAY TRACING RESULTS (NOVEMBER PROFILE)

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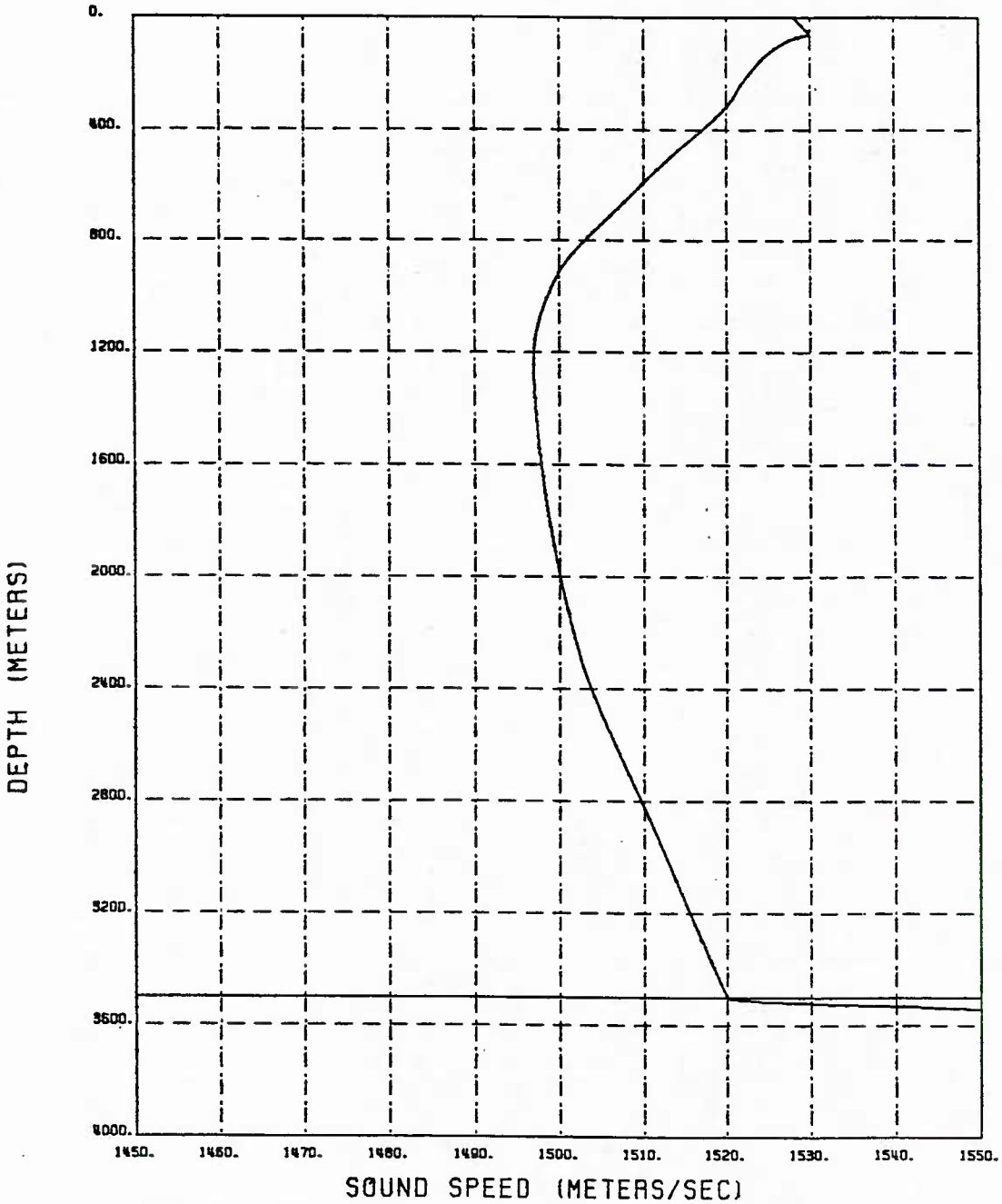

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SOURCE AIM = 11.0 DEGREES
SOURCE WIDTH = 10.0 METERS

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BOTTOM DEPTH = 3501.3 METERS
VERTICAL MESH SPACING = 1.81 METERS
BOTTOM ATTENUATION CONSTANT = 0.001000
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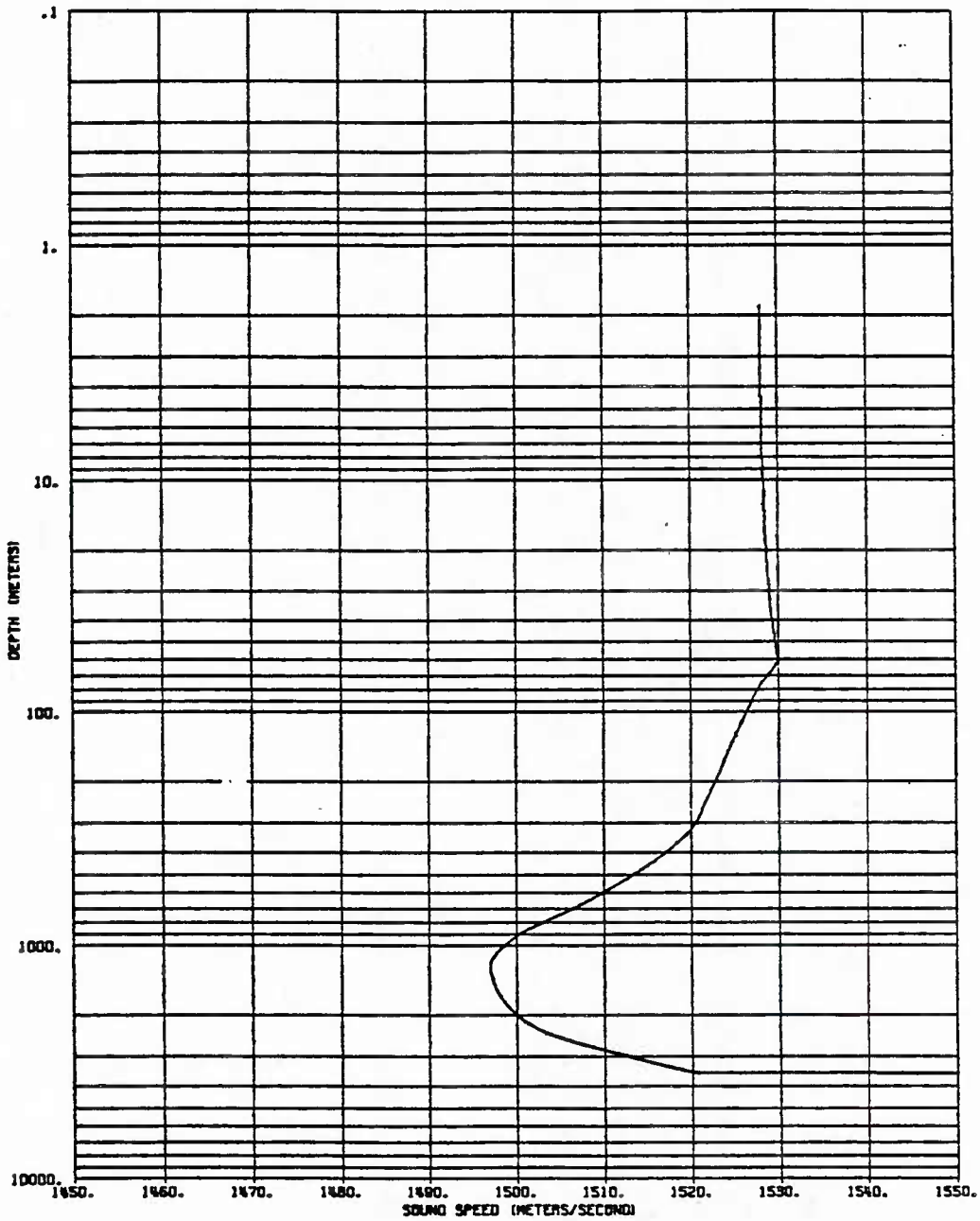
RANGE MESH SPACING = 62.50 METERS



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SOURCE WIDTH = 10.0 METERS

PROBLEM DEPTH = 3700.0 METERS
BOTTOM DEPTH = 3501.3 METERS
VERTICAL MESH SPACING = 1.81 METERS
BOTTOM ATTENUATION CONSTANT = 0.001000
ATTENUATION SCALE LENGTH = 500.0
SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 138750. METERS
RANGE MESH SPACING = 62.50 METERS

RANGE = 5 MILES

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TM No. 811061

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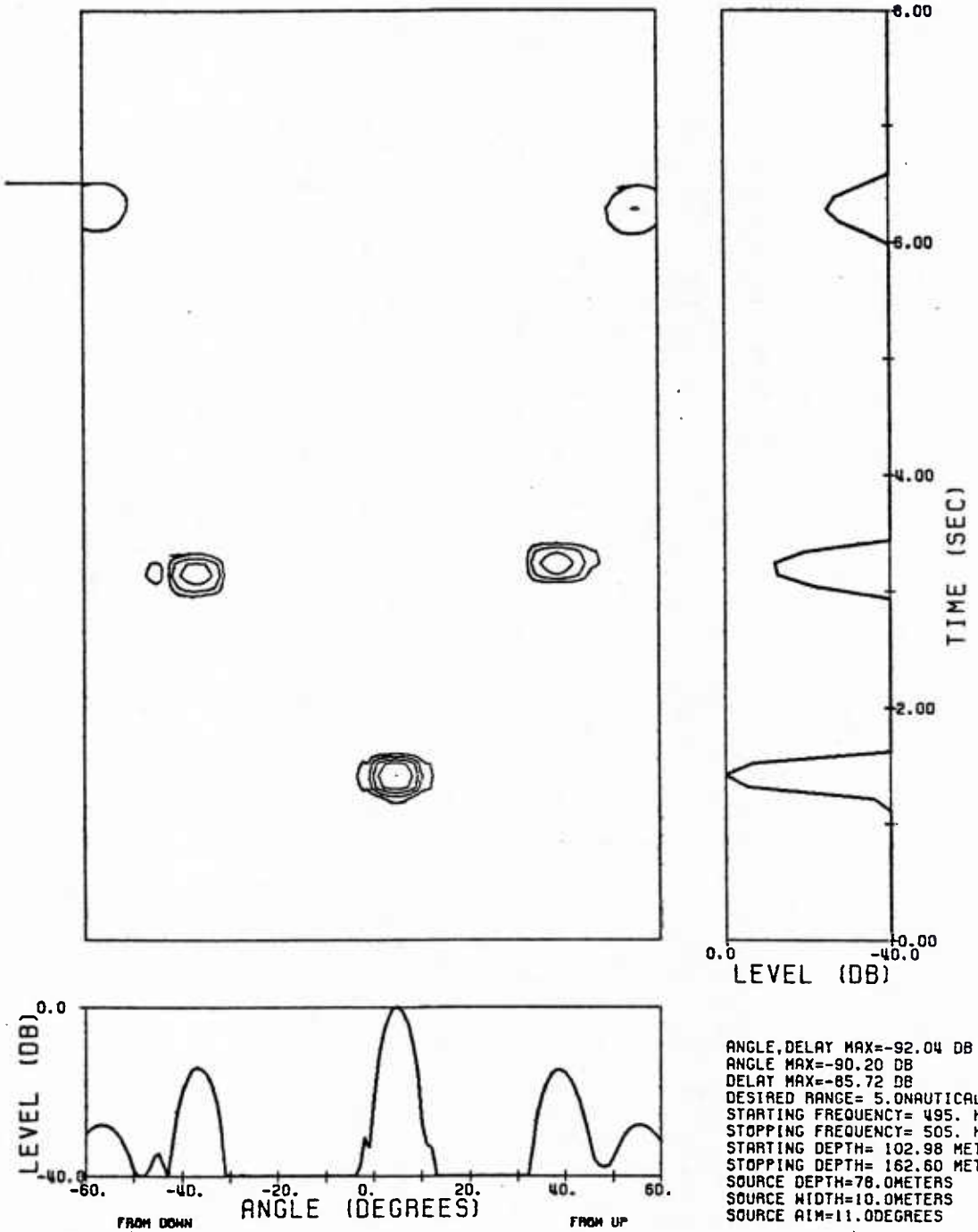

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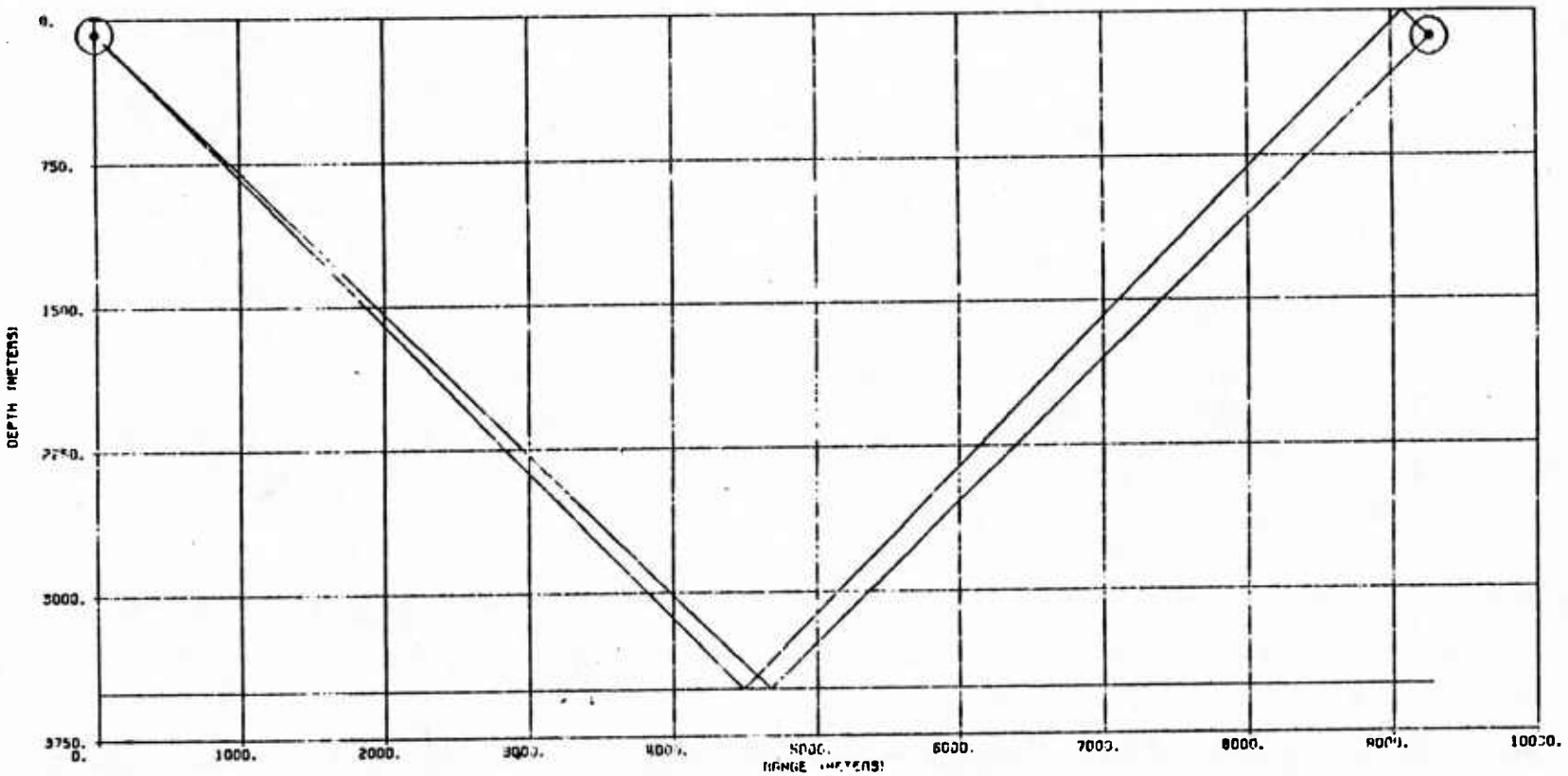
SOURCE AIM=11.0DEGREES



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SOURCE RANGE = 0.00 METERS

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TARGET RANGE = 9266.55 METERS

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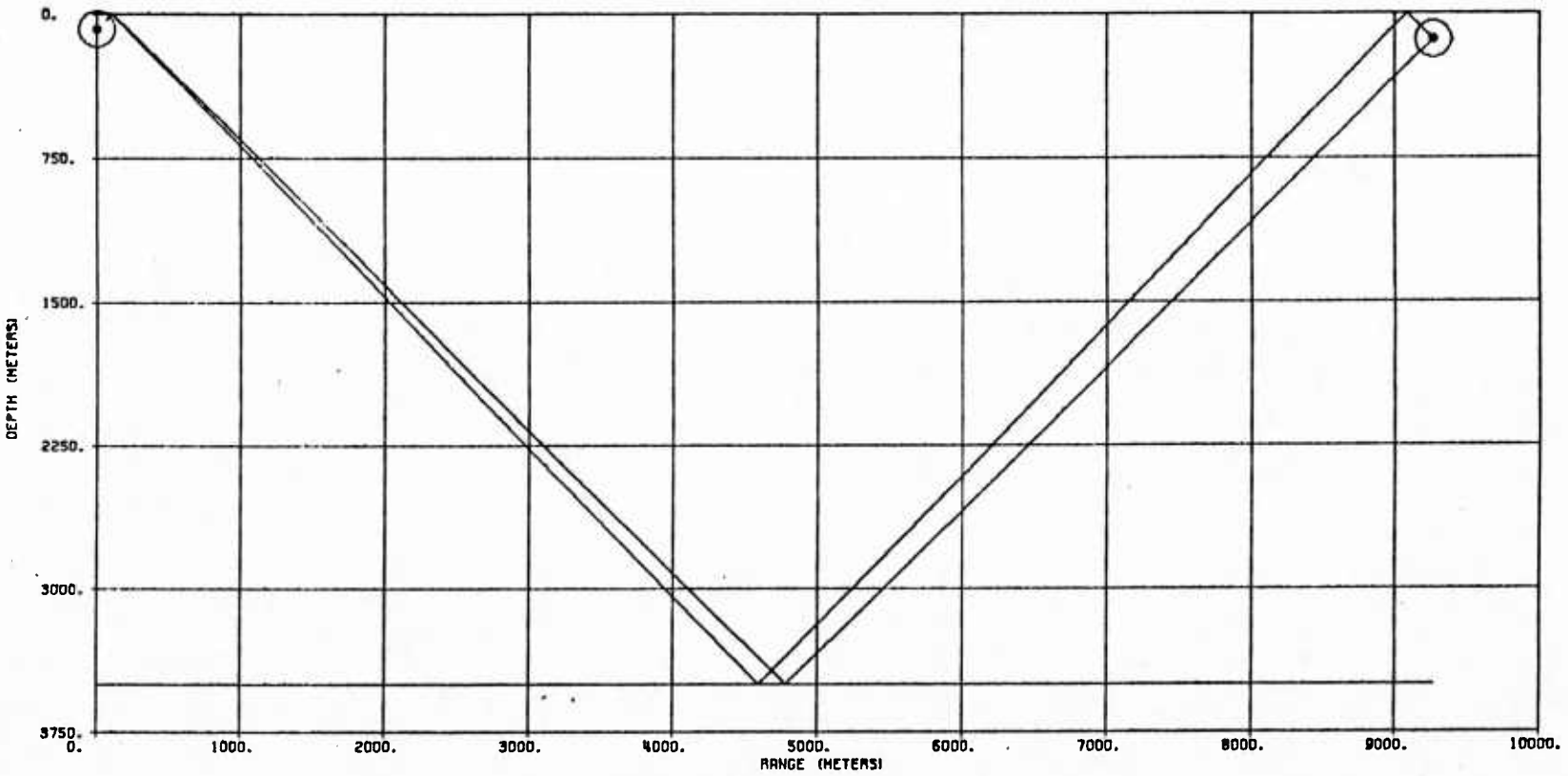

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SOURCE RANGE = 0.00 METERS

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TARGET RANGE = 9266.55 METERS

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-36.9	37.1	7.789	-36.9	37.3	81.10	3

A9/A10 REVERSE BLANK

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5-SEP-80 14:09:41

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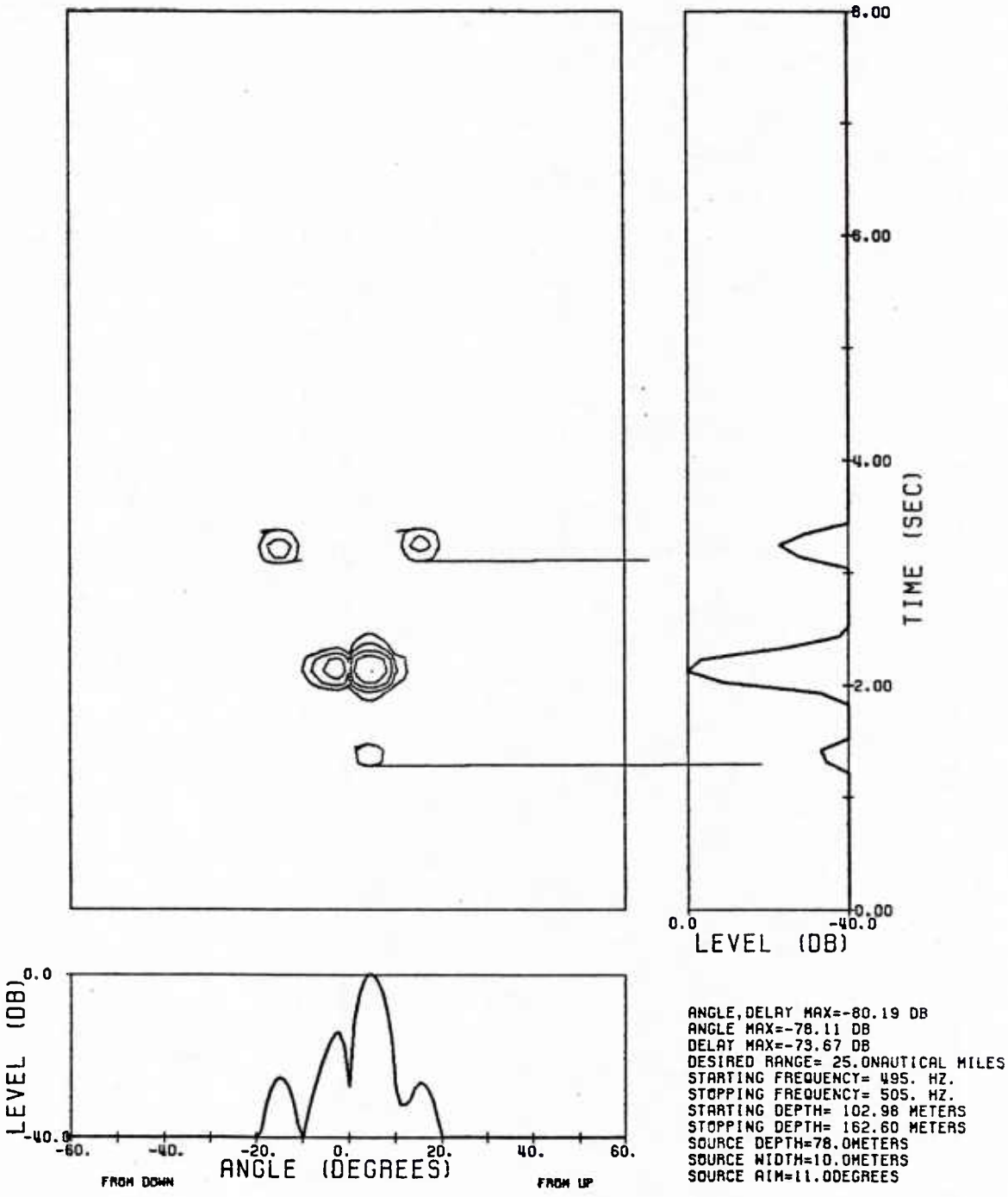

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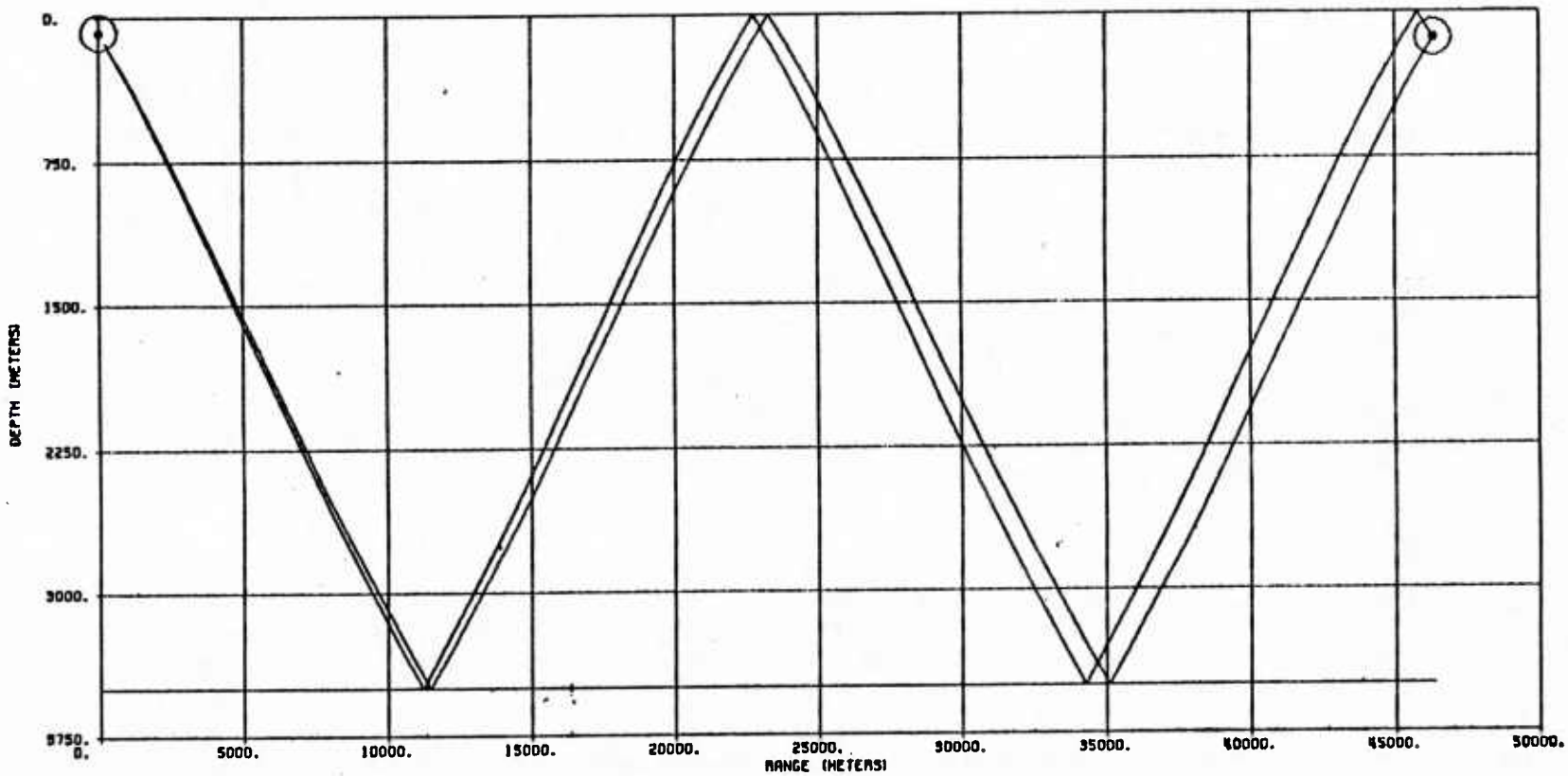
SOURCE AIM=11.0DEGREES



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TARGET RANGE = 46332.74 METERS

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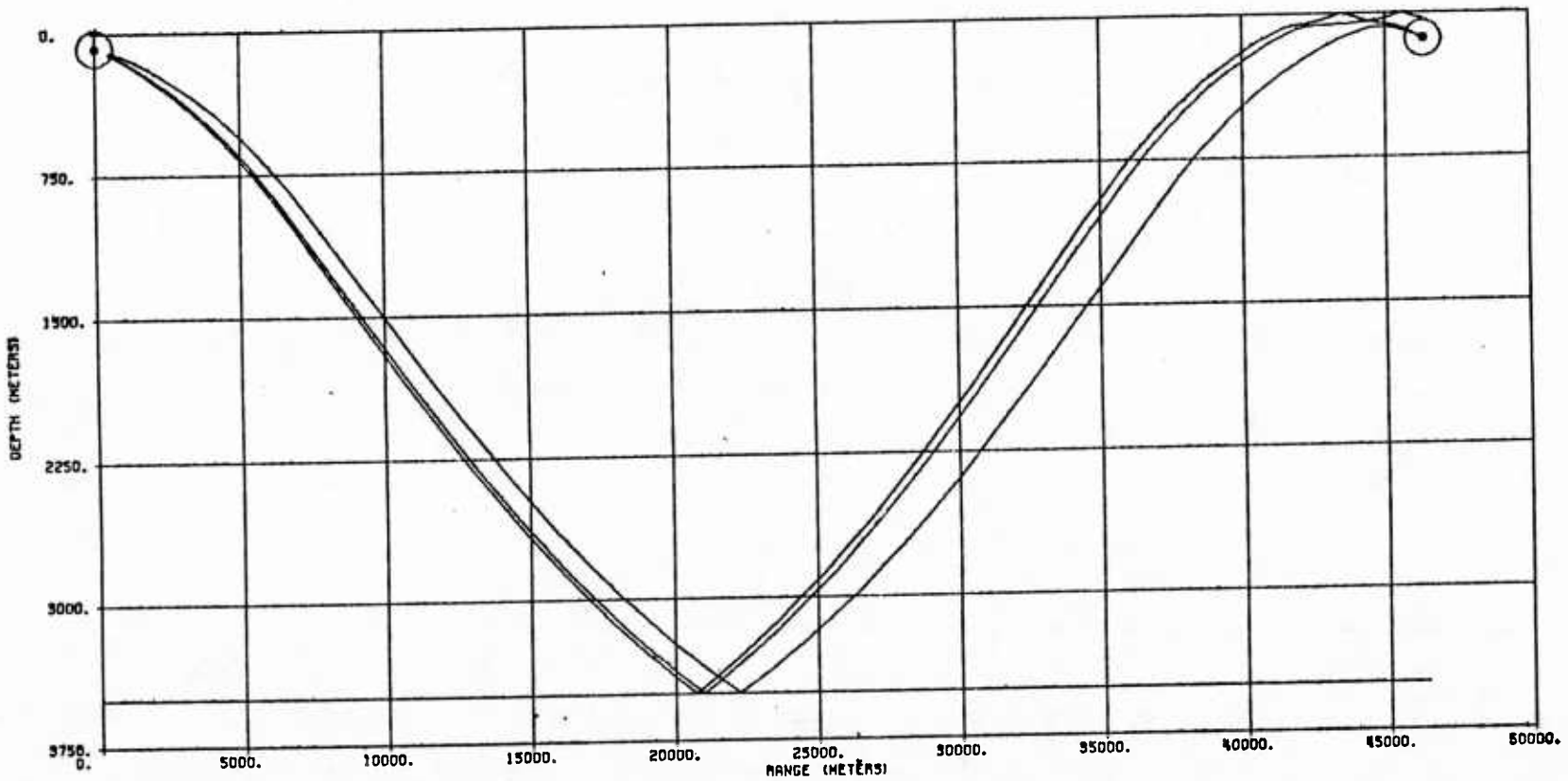
14.2	14.7	32.118	-14.2	15.3	92.33	4



RUN FOR BT21C

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SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
1.6	4.0	31.062	0.0	6.0	84.20	2
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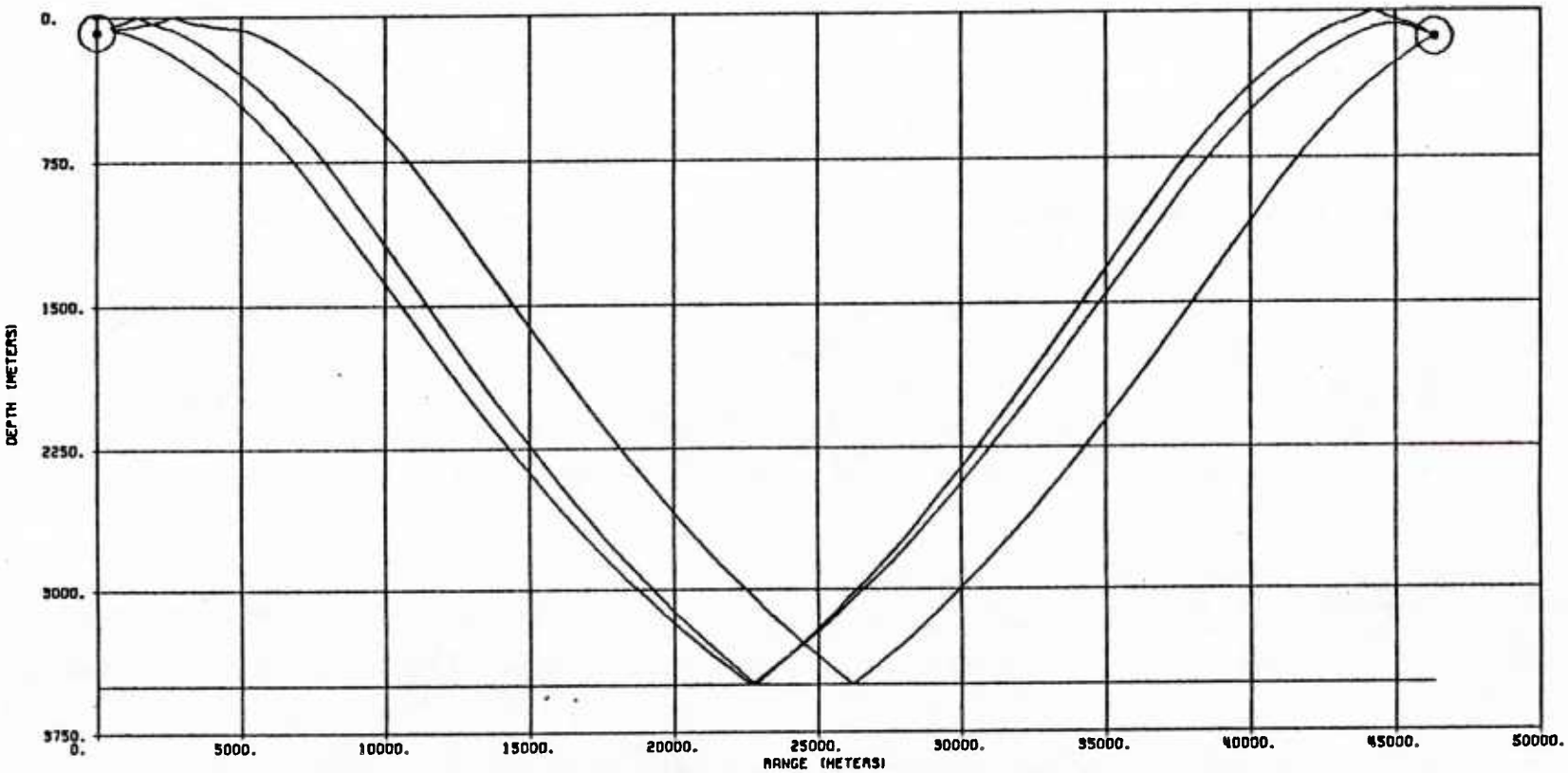
3.0	4.7	31.065	-2.9	6.5	108.46	2



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SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

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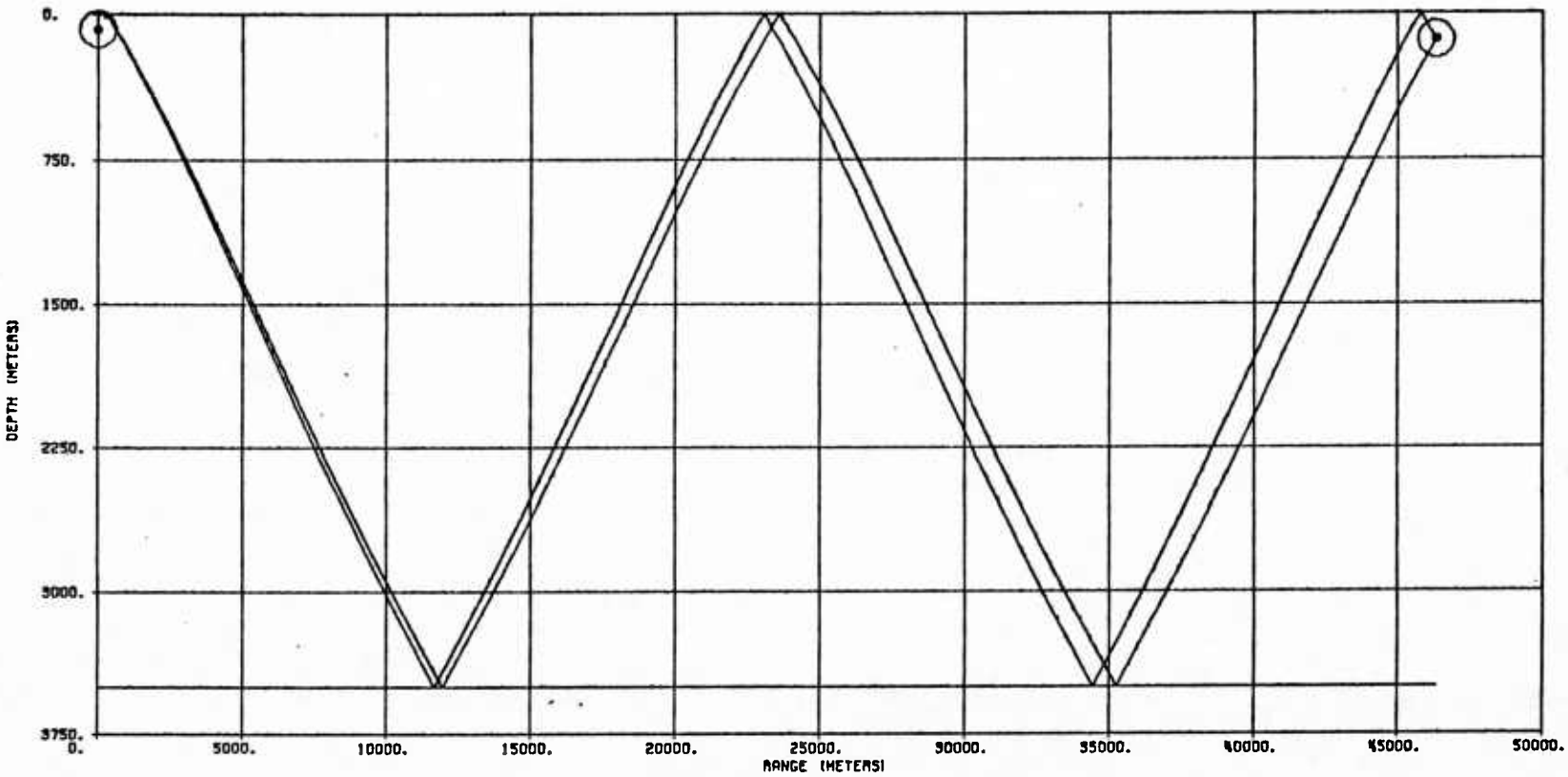

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SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
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-14.5	14.9	32.143	-14.4	15.6	92.40	5

A17/A18 REVERSE BLANK

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TM No. 811061

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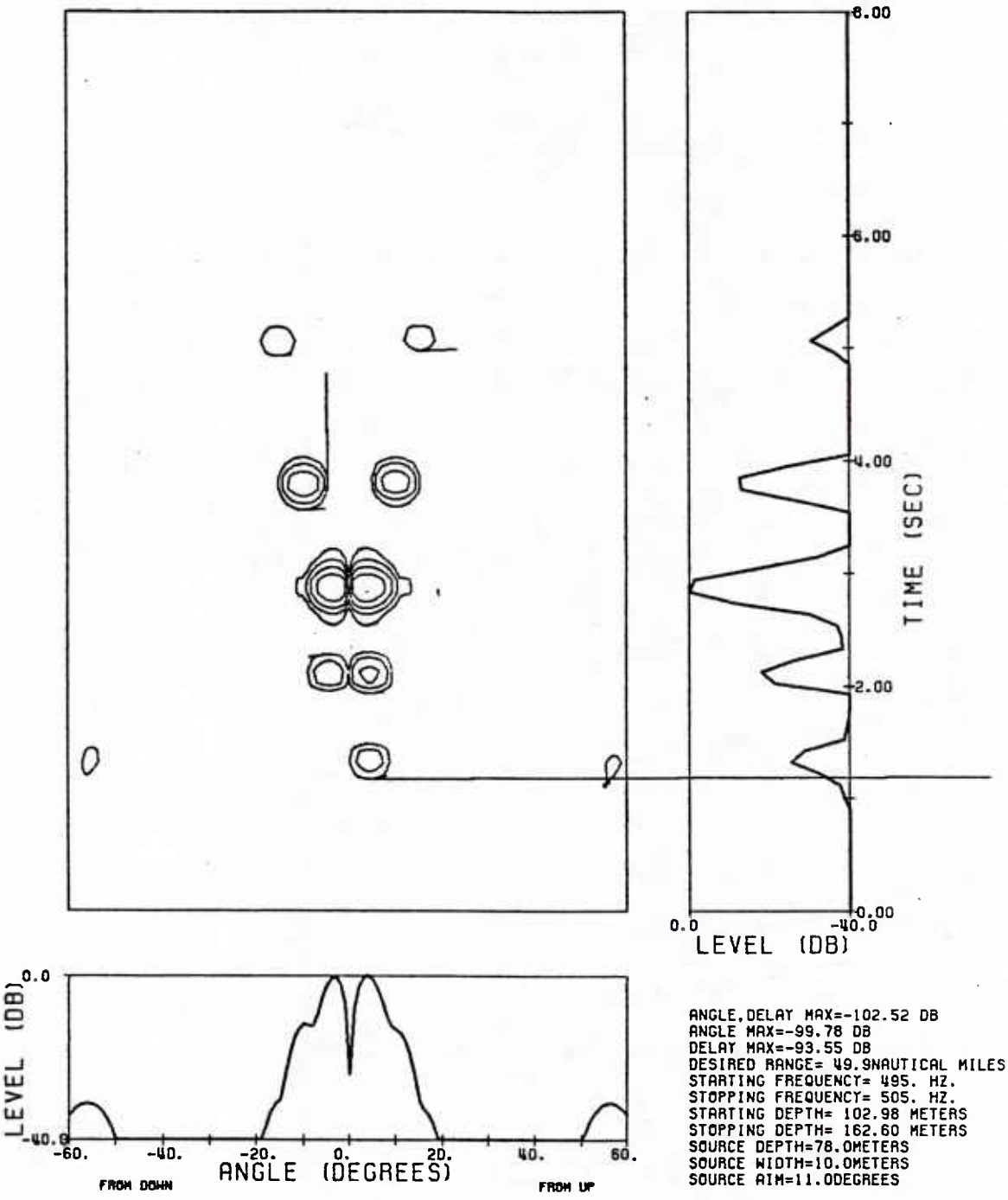

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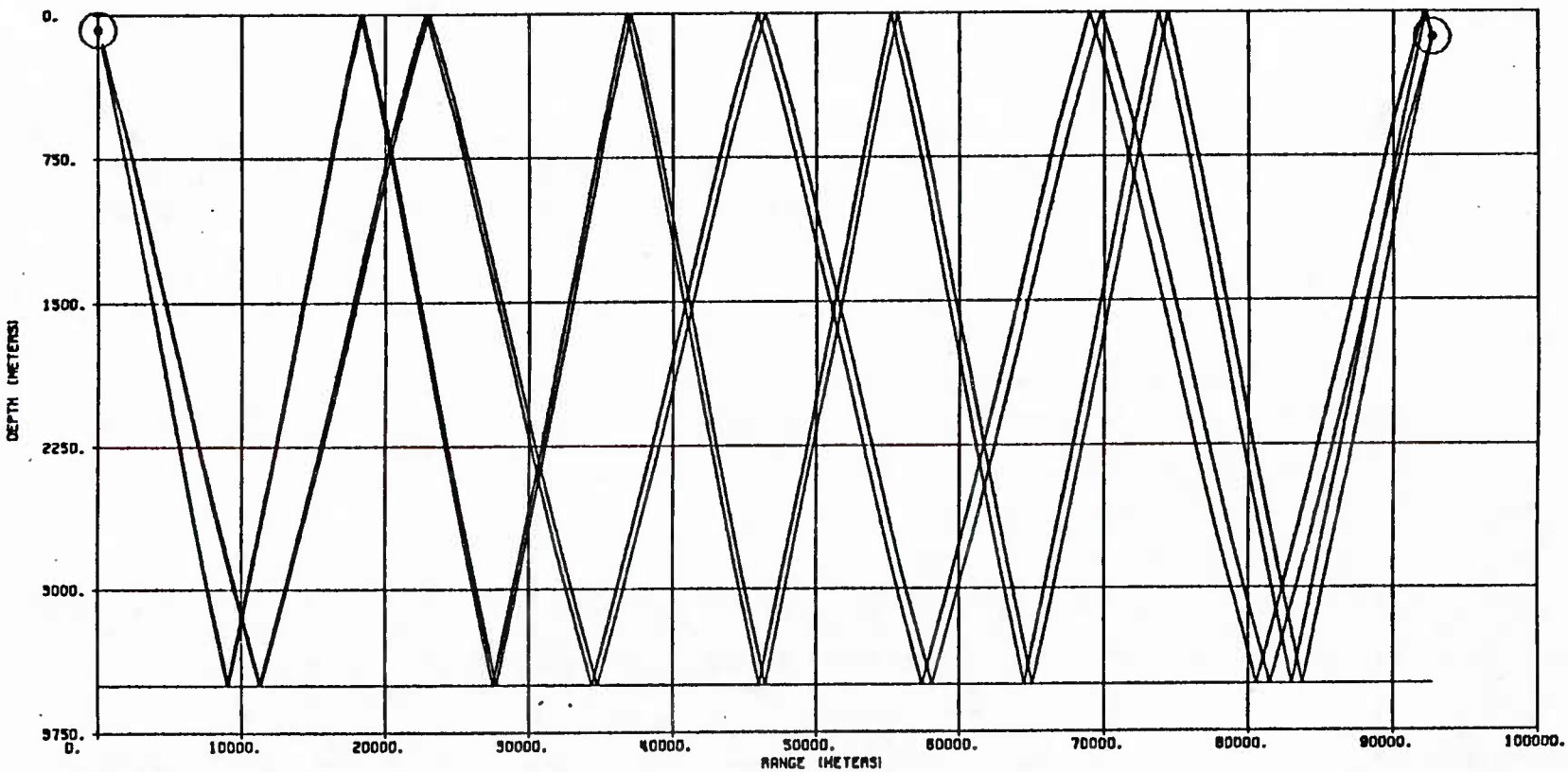
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=11.0DEGREES

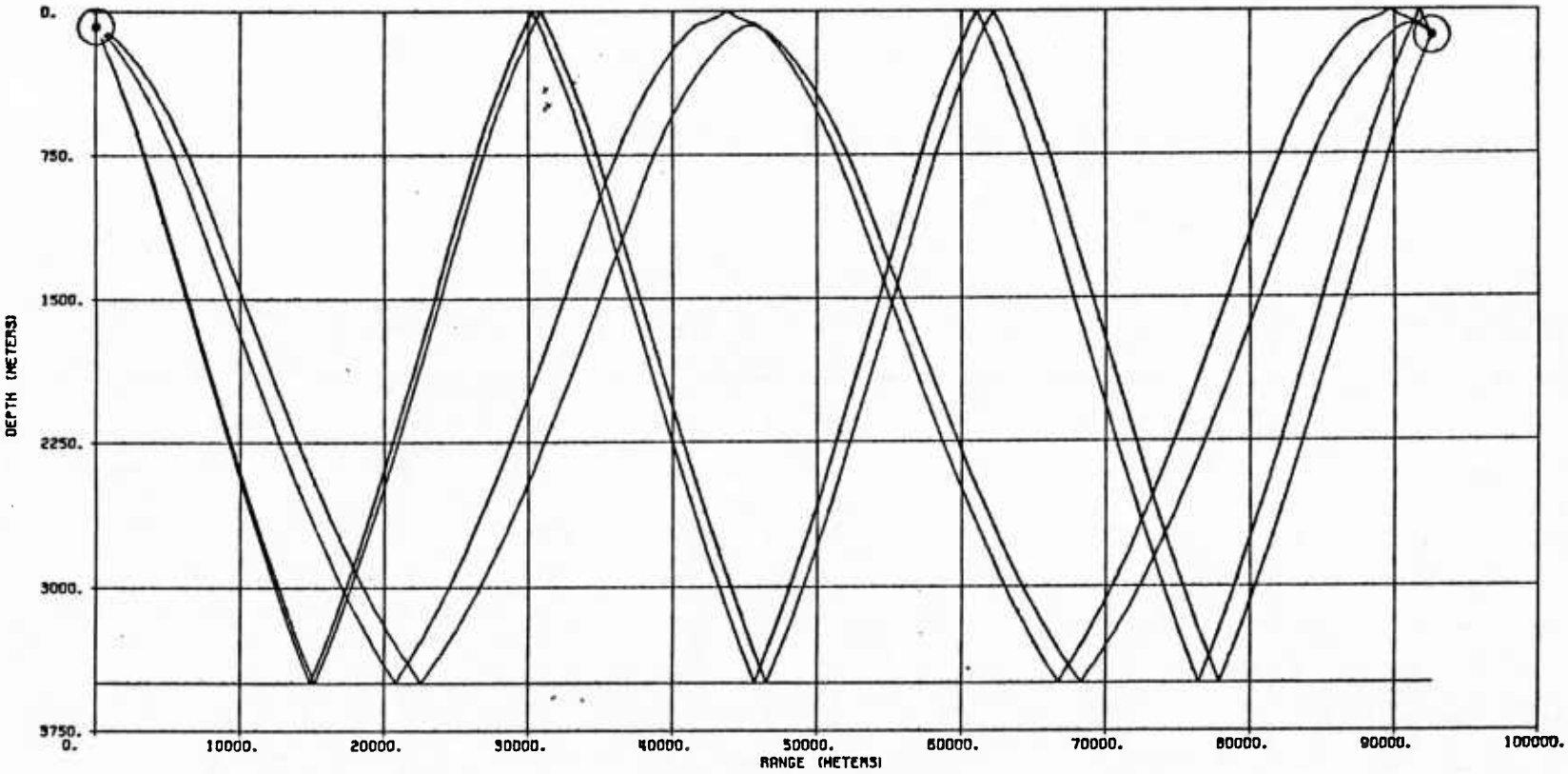


RUN FOR BT22C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
13.9	-14.4	64.184	-13.9	15.1	98.28	7
14.2	14.6	64.227	-14.1	15.3	98.35	8
18.4	-18.8	65.672	-18.4	19.3	98.98	9
18.6	19.0	65.728	-18.6	19.5	99.02	10

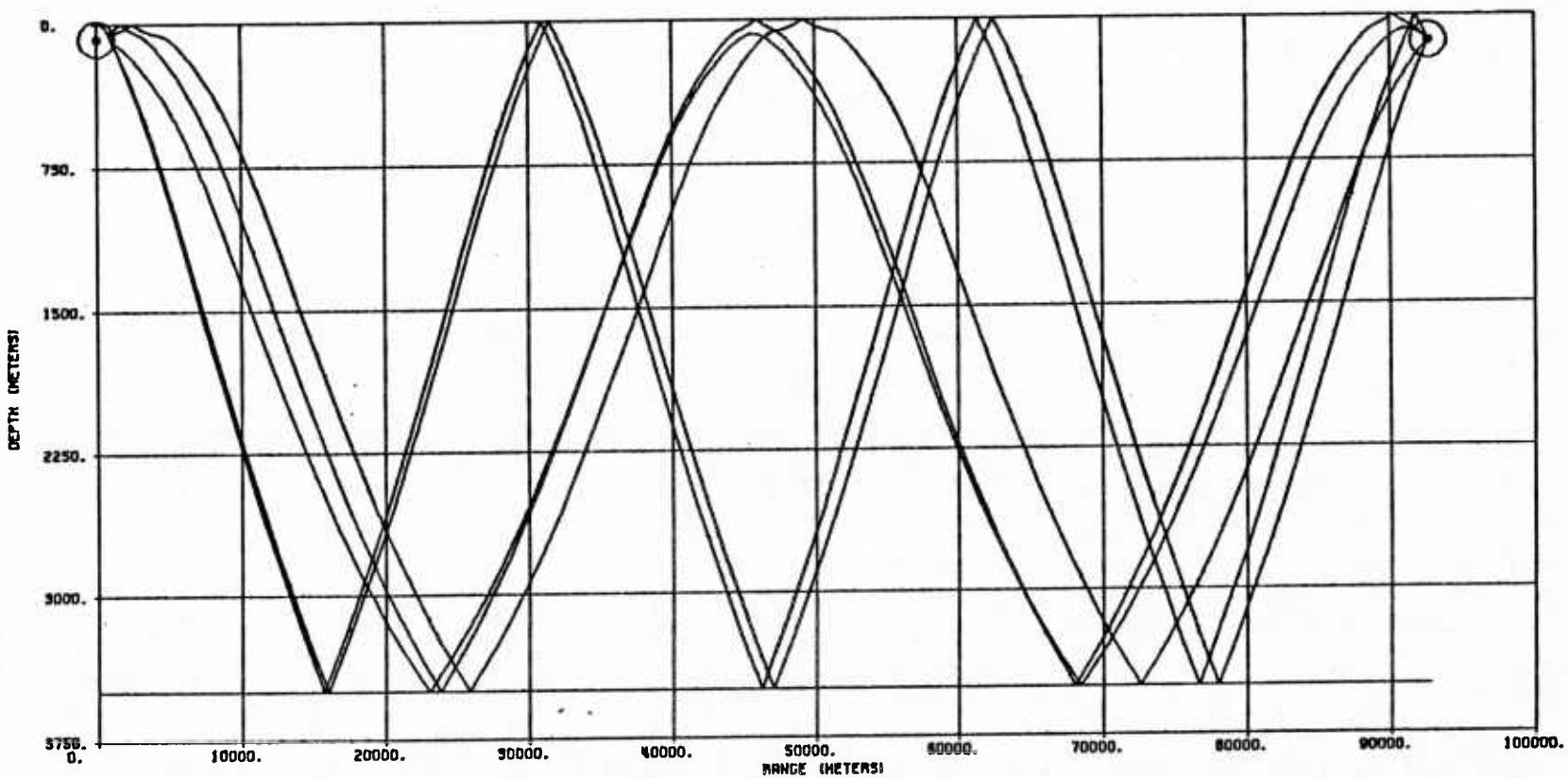


RUN FOR BT22C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
1.1	3.8	62.123	0.0	5.9	88.48	4
3.2	4.9	62.126	-3.1	6.6	97.65	4
8.8	-9.6	63.000	-8.8	10.6	96.93	5
9.1	9.8	63.027	-9.1	10.8	97.10	6

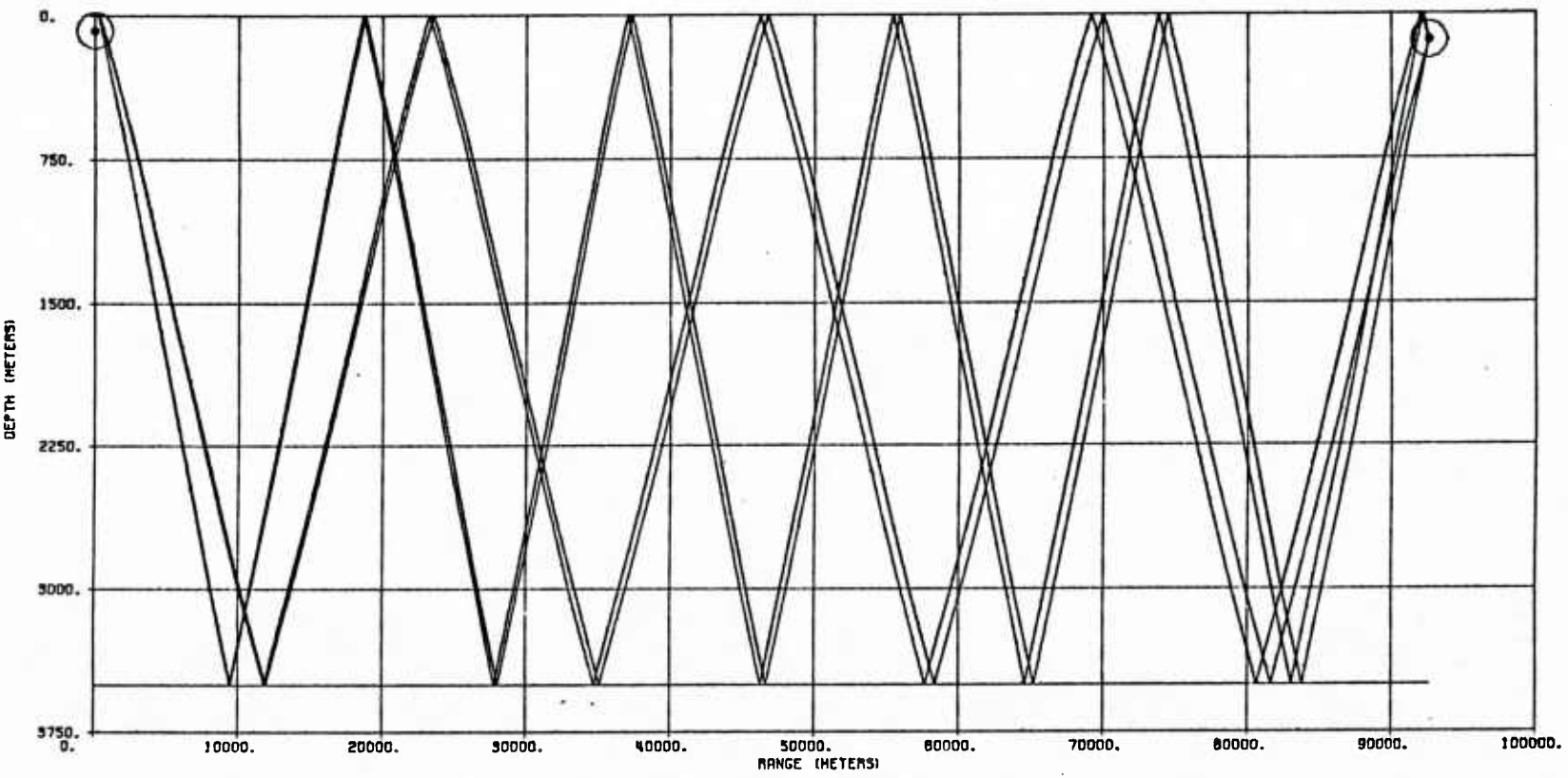


RUN FOR BT22C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-3.1	-4.8	62.120	-3.0	6.6	99.12	4
-1.4	3.9	62.123	0.0	6.0	88.70	5
-9.6	5.1	62.130	-3.4	6.8	96.77	5
-9.0	-9.7	63.015	-9.0	10.7	97.05	6
-8.3	10.0	63.043	-8.3	11.0	97.23	7



RUN FOR BT22C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

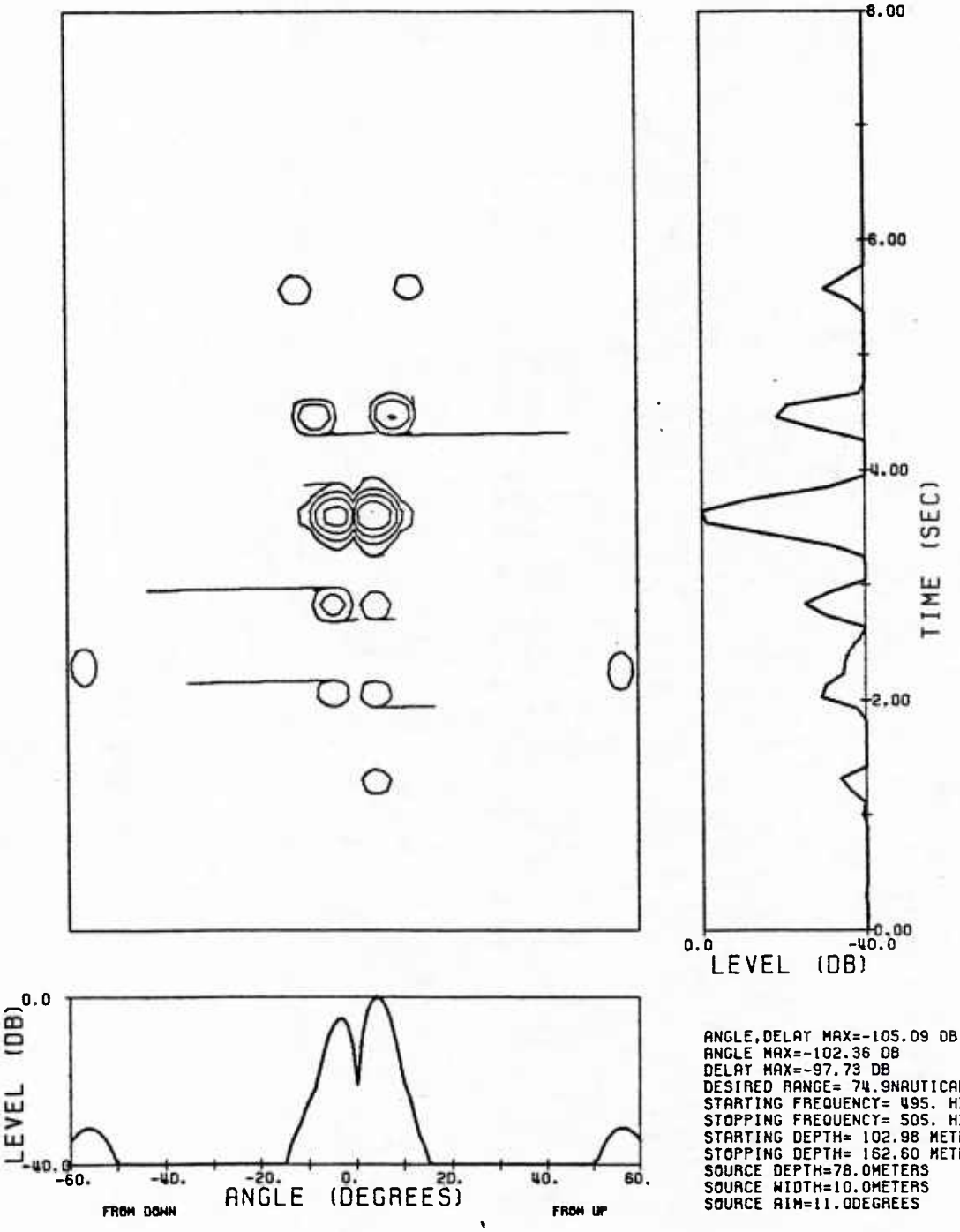
TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-14.1	-14.5	64.209	-14.1	15.2	98.32	8
-14.3	14.8	64.252	-14.3	15.4	98.38	9
-18.5	-18.9	65.704	-18.5	19.4	99.00	10
-18.7	19.1	65.761	-18.7	19.6	99.03	11

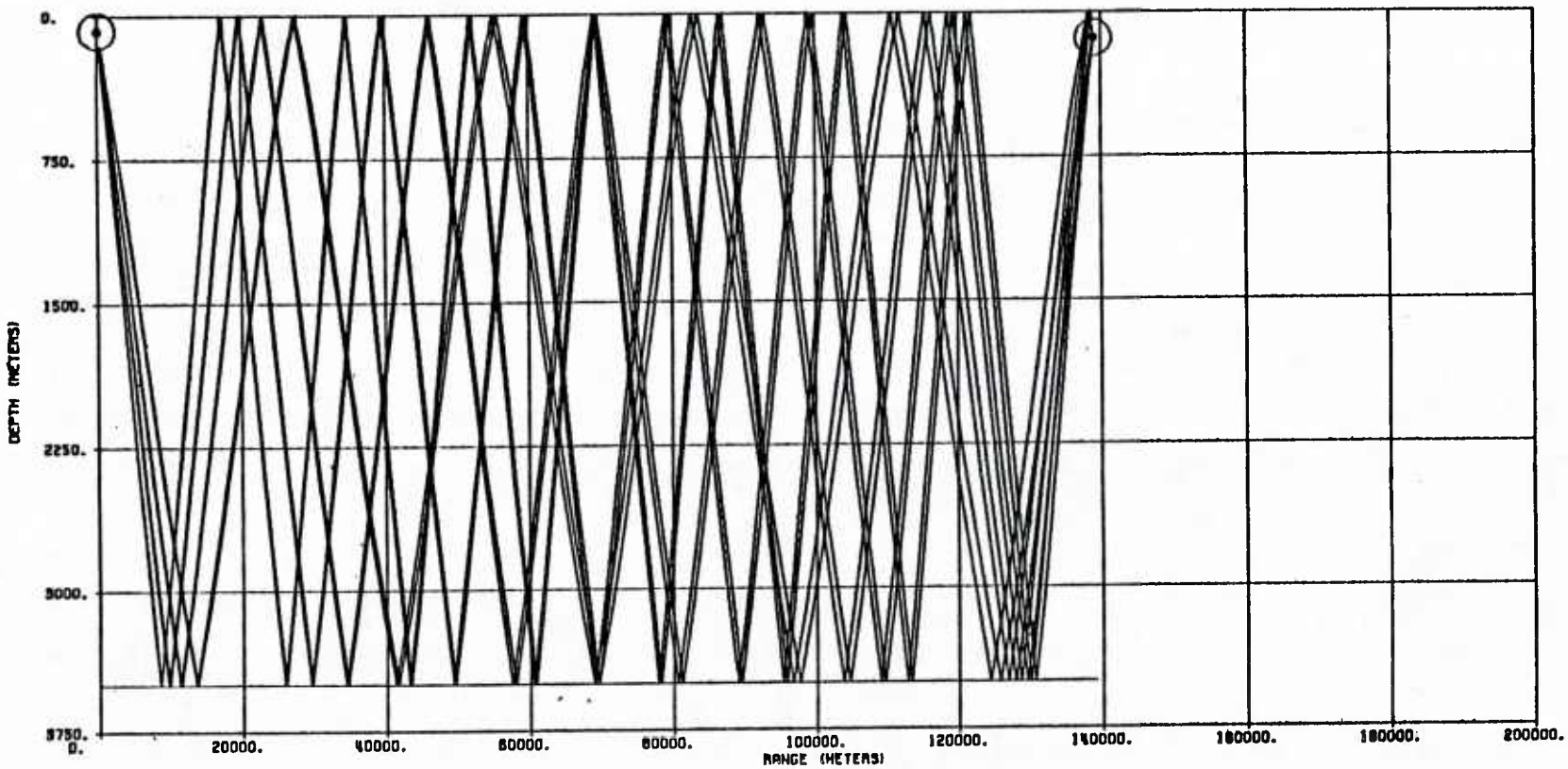
RANGE = 75 MILES

REVERSE BLANK

E11DEC35 RIDGE



ANGLE,DELAY MAX=-105.09 DB
ANGLE MAX=-102.36 DB
DELAY MAX=-97.73 DB
DESIRED RANGE= 74.9NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=11.0DEGREES

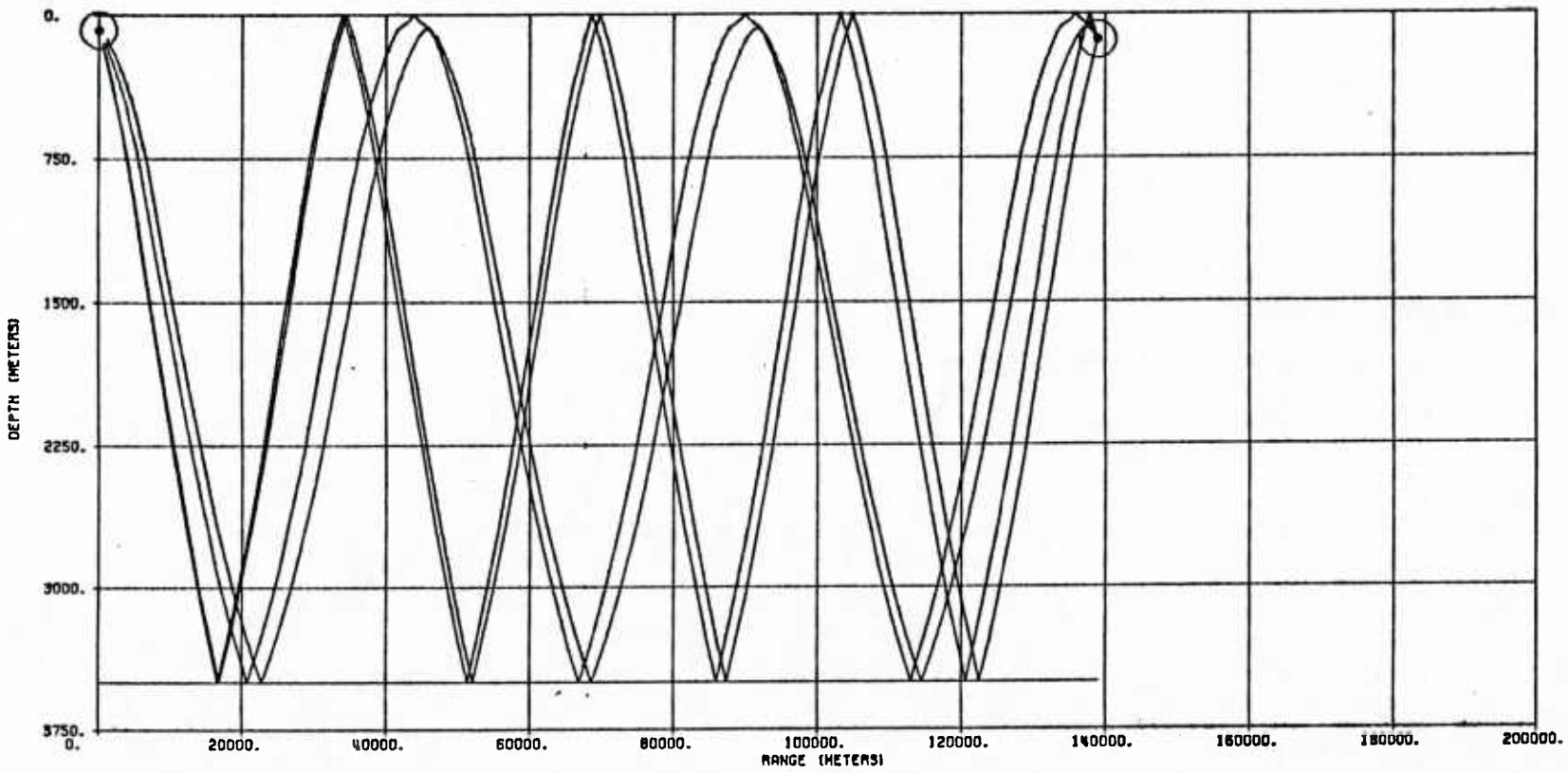


RUN FOR BT23C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
10.7	-11.3	95.053	-10.7	12.2	101.07	9
10.9	11.5	95.086	-10.9	12.3	101.17	10
14.0	-14.5	96.293	-14.0	15.1	101.81	11
14.2	14.6	96.336	-14.1	15.3	101.85	12
17.0	-17.4	97.735	-17.0	18.0	102.31	13
17.2	17.5	97.788	-17.1	18.1	102.33	14
19.8	-20.2	99.373	-19.8	20.7	102.69	15
20.0	20.3	99.433	-20.0	20.8	102.70	16

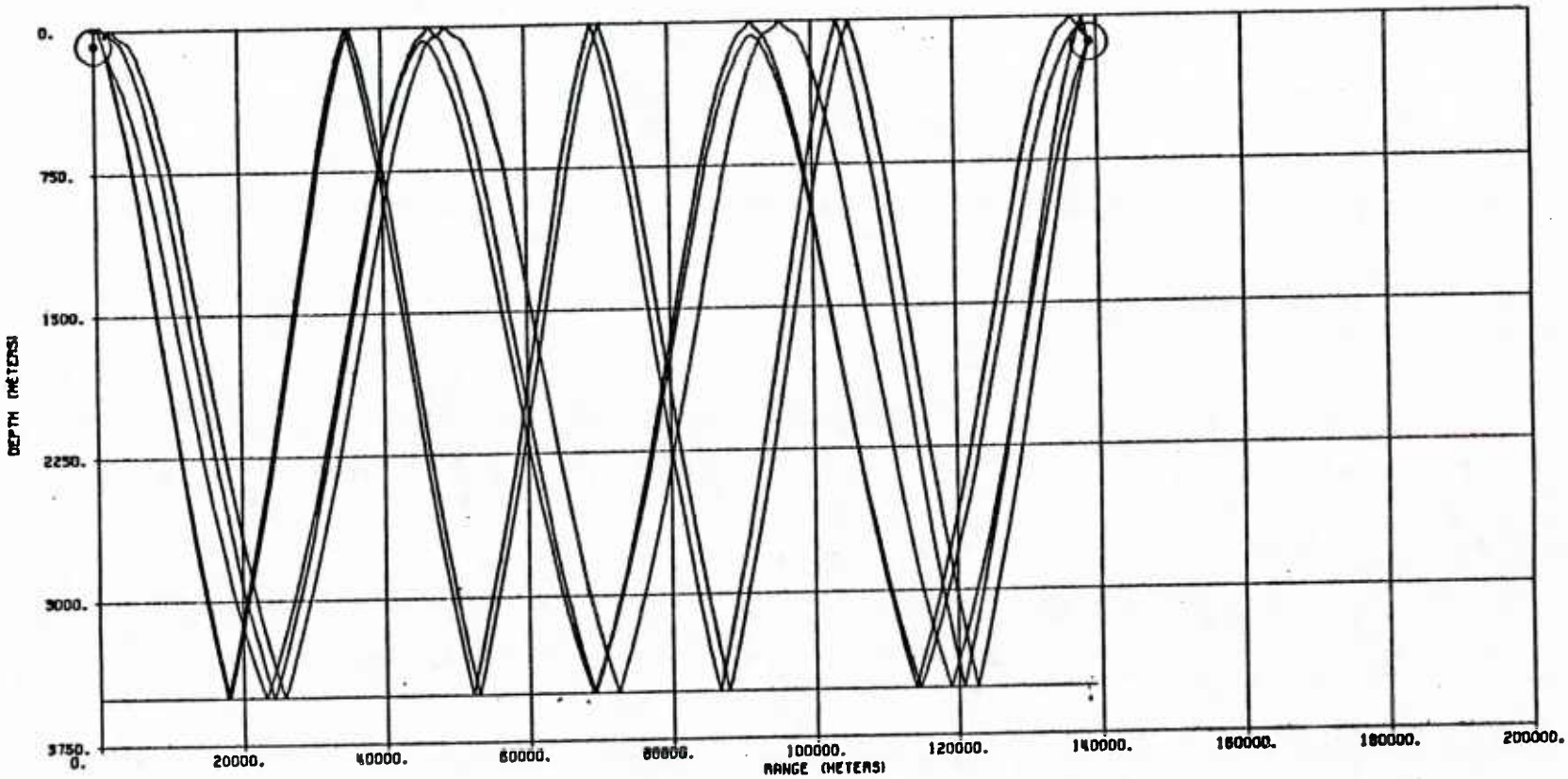


RUN FOR BT23C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
0.9	3.8	93.183	0.0	5.9	90.85	6
3.2	4.9	93.187	-3.1	6.6	101.34	6
7.0	-7.9	94.019	-6.9	9.0	99.73	7
7.2	8.1	94.041	-7.2	9.2	99.94	8

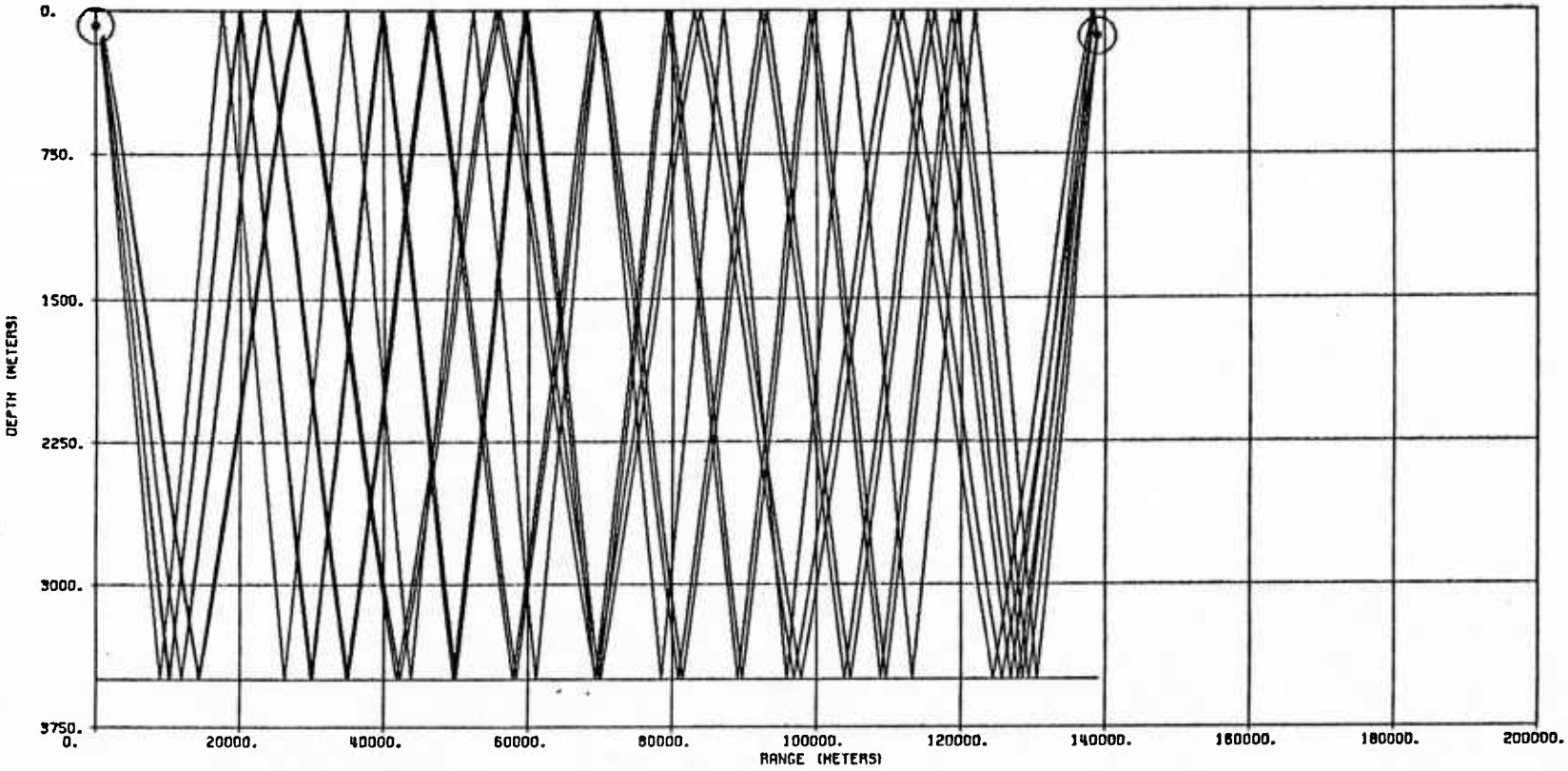


RUN FOR BT23C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-3.1	-4.8	93.181	-3.0	6.6	102.54	6
-1.1	3.8	93.183	0.0	5.9	90.95	7
-3.4	5.0	93.191	-3.3	6.7	100.54	7
-7.1	-8.0	94.031	-7.1	9.2	99.87	8
-7.4	8.2	94.059	-7.3	9.4	100.04	9



RUN FOR BT23C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

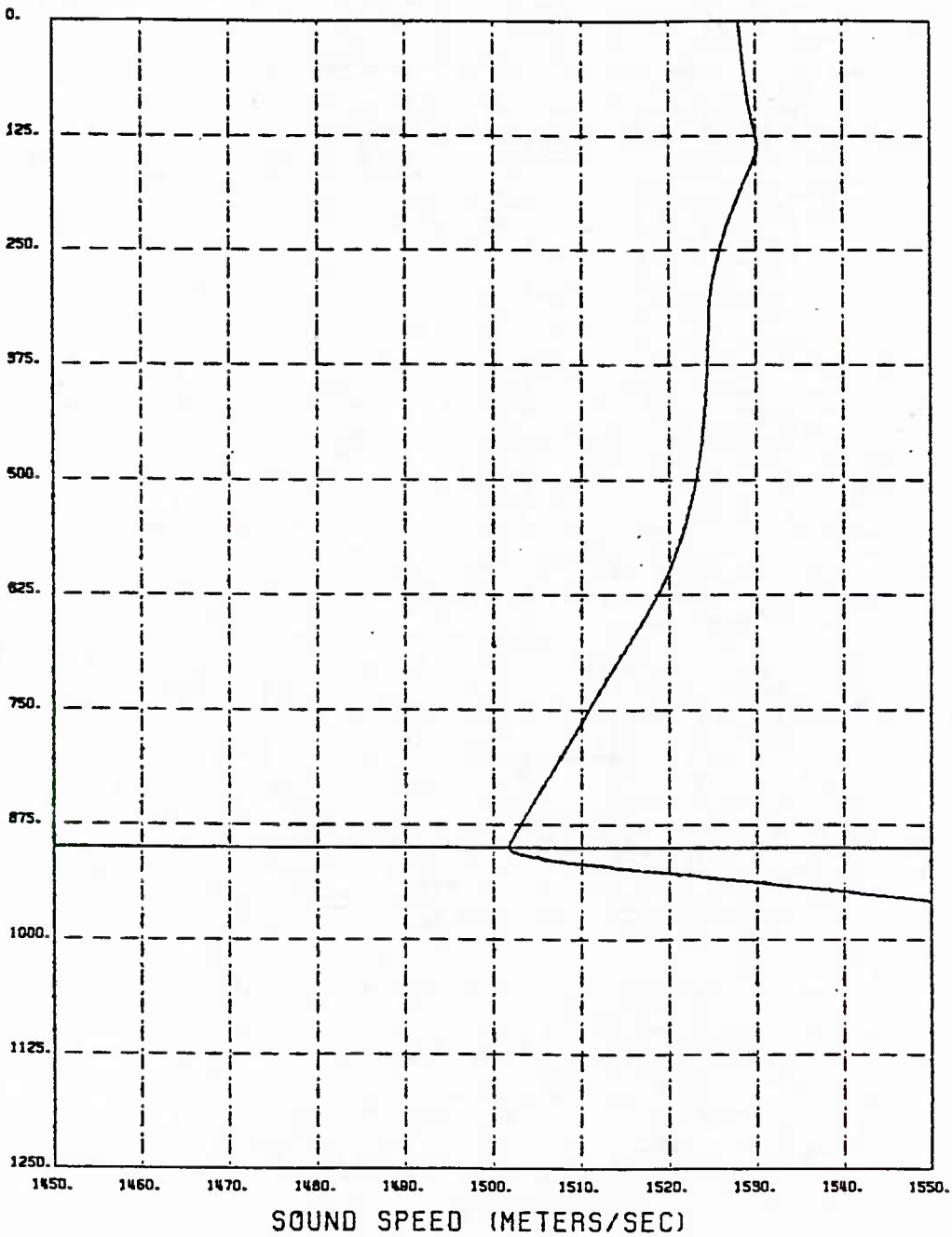
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-10.8	-11.4	95.072	-10.8	12.3	101.12	10
-11.0	11.6	95.105	-11.0	12.4	101.18	11
-14.1	-14.6	96.317	-14.1	15.2	101.83	12
-14.2	14.7	96.361	-14.2	15.4	101.88	13
-17.1	-17.5	97.765	-17.1	18.0	102.33	14
-17.2	17.6	97.818	-17.2	18.2	102.35	15
-19.9	-20.3	99.407	-19.8	20.7	102.69	16

A33/A34 REVERSE BLANK

APPENDIX B

BLAKE PLATEAU PE & RAY TRACING RESULTS (FEBRUARY PROFILE)

REVERSE BLANK

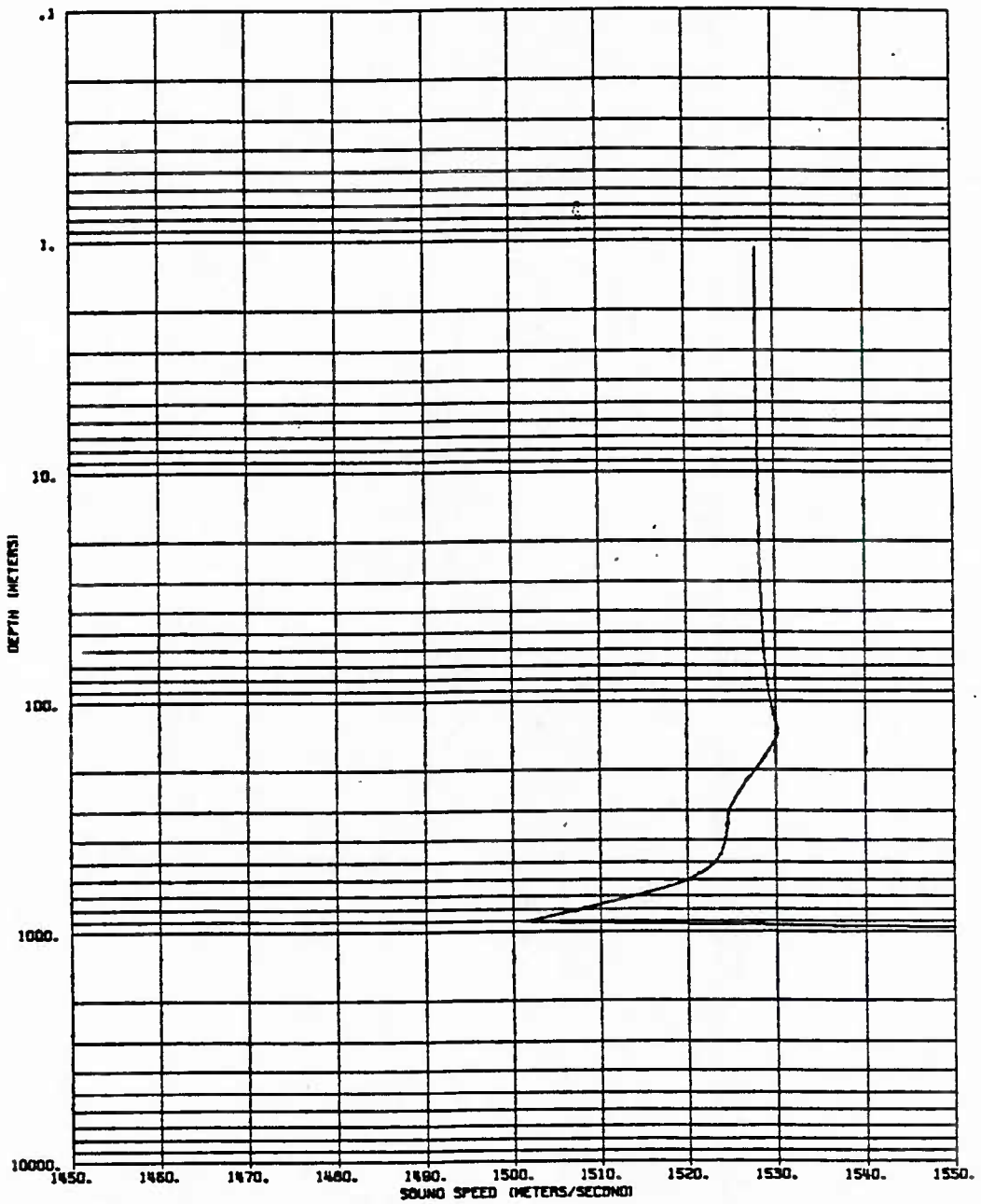


FREQUENCY = 460.0 HZ

SOURCE DEPTH = 78.0 METERS
SOURCE AIM = 4.0 DEGREES
SOURCE WIDTH = 6.1 METERS

PROBLEM DEPTH = 1100.0 METERS
BOTTOM DEPTH = 900.2 METERS
VERTICAL MESH SPACING = 1.07 METERS
BOTTOM ATTENUATION CONSTANT = 0.001000
ATTENUATION SCALE LENGTH = 500.0
SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 138750. METERS
RANGE MESH SPACING = 62.50 METERS



A17CFEB90 BLAKE

FREQUENCY = 460.0 HZ

SOURCE DEPTH = 78.0 METERS
SOURCE AIM = 4.0 DEGREES
SOURCE WIDTH = 6.1 METERS

PROBLEM DEPTH = 1100.0 METERS
BOTTOM DEPTH = 900.2 METERS
VERTICAL MESH SPACING = 1.07 METERS
BOTTOM ATTENUATION CONSTANT = 0.001000
ATTENUATION SCALE LENGTH = 500.0
SVP TRANSITION REGION=500.0 METERS

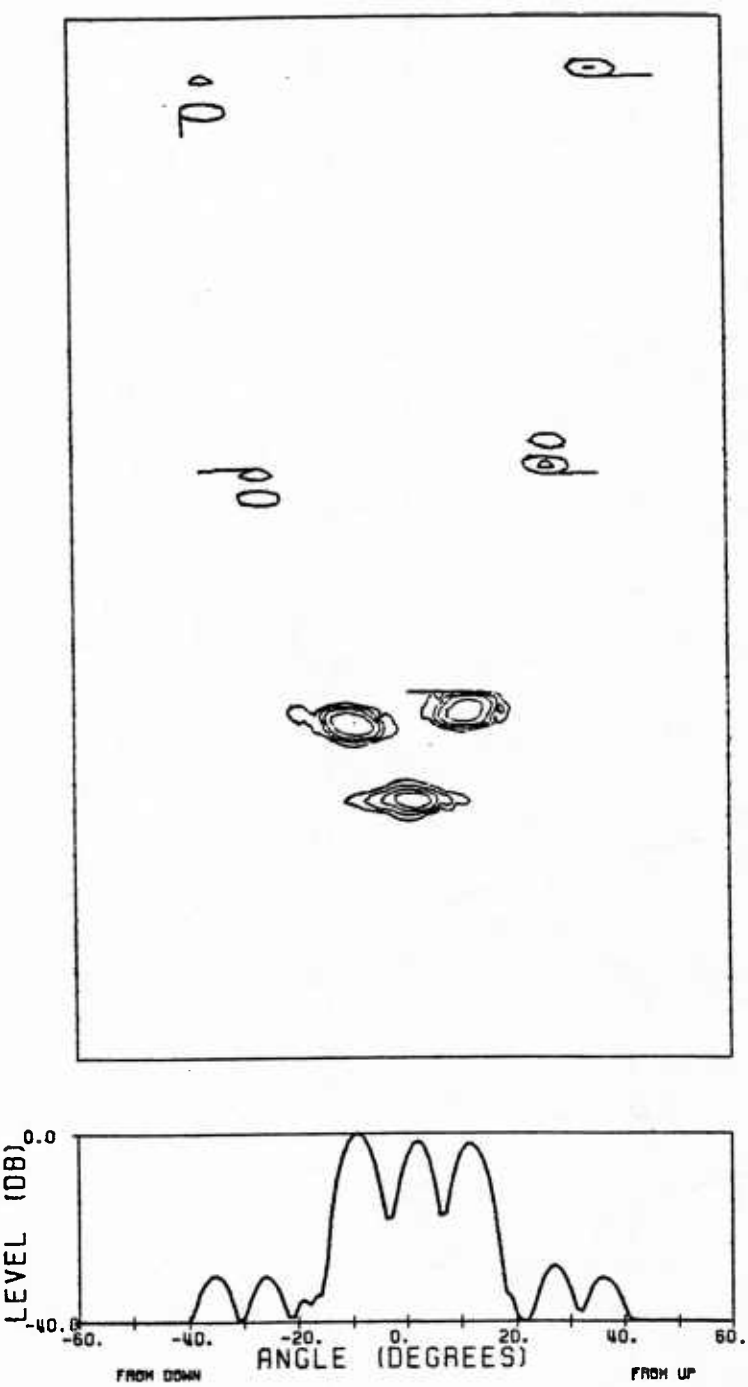
PROBLEM RANGE = 138750. METERS
RANGE MESH SPACING = 62.50 METERS

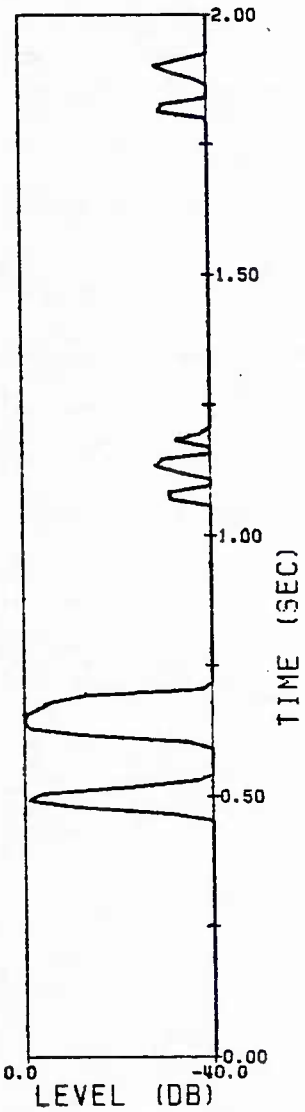
RANGE = 5 MILES

REVERSE BLANK

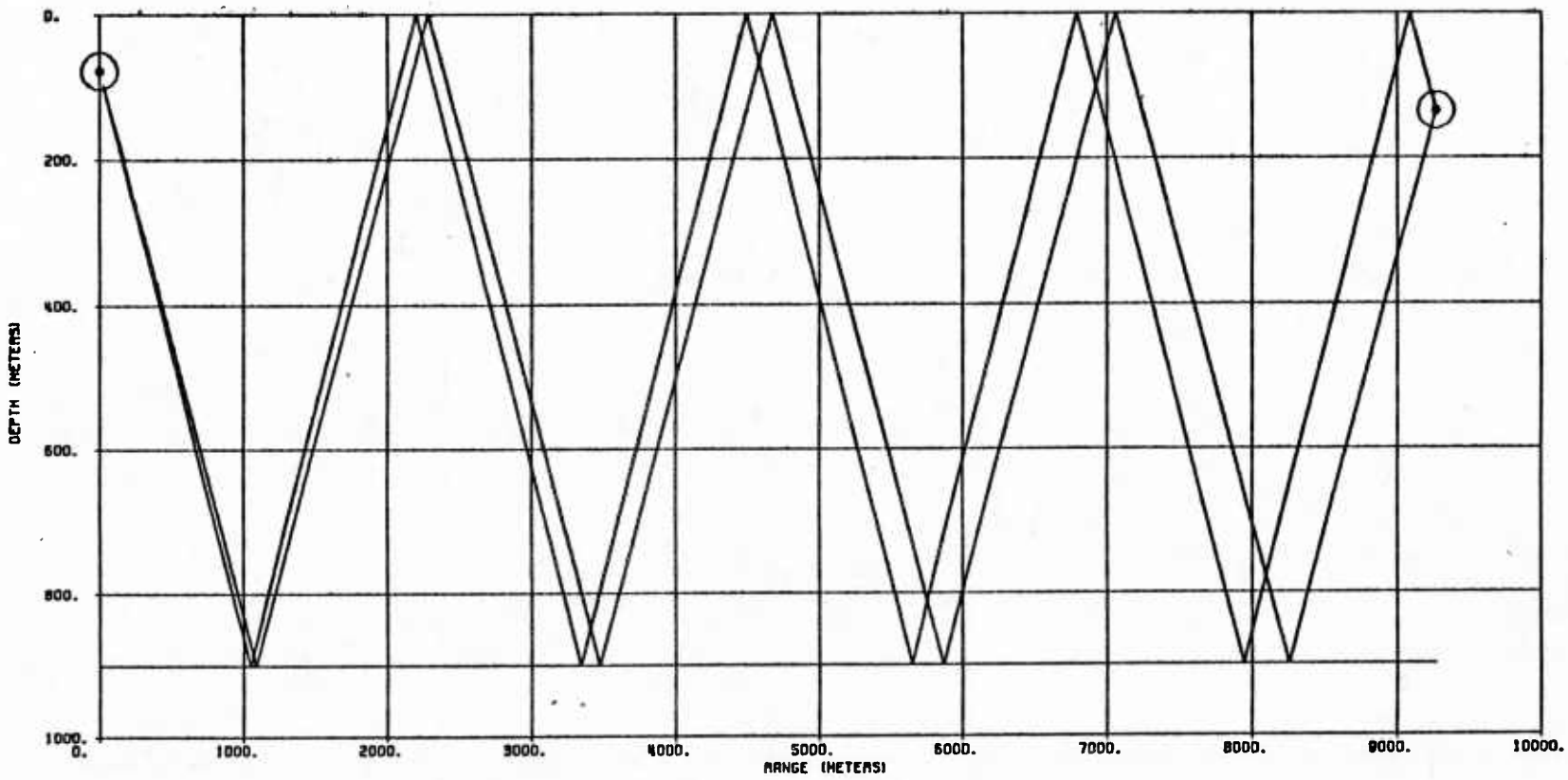
TM No. 811061

A17CFEB90 BLAKE





ANGLE,DELAY MAX=-81.72 DB
ANGLE MAX=-78.16 DB
DELAY MAX=-75.02 DB
DESIRED RANGE= 5.0NAUTICAL MILES
STARTING FREQUENCY= 460. HZ.
STOPPING FREQUENCY= 540. HZ.
STARTING DEPTH= 104.20 METERS
STOPPING DEPTH= 164.36 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=6.1METERS
SOURCE AIM=4.0DEGREES

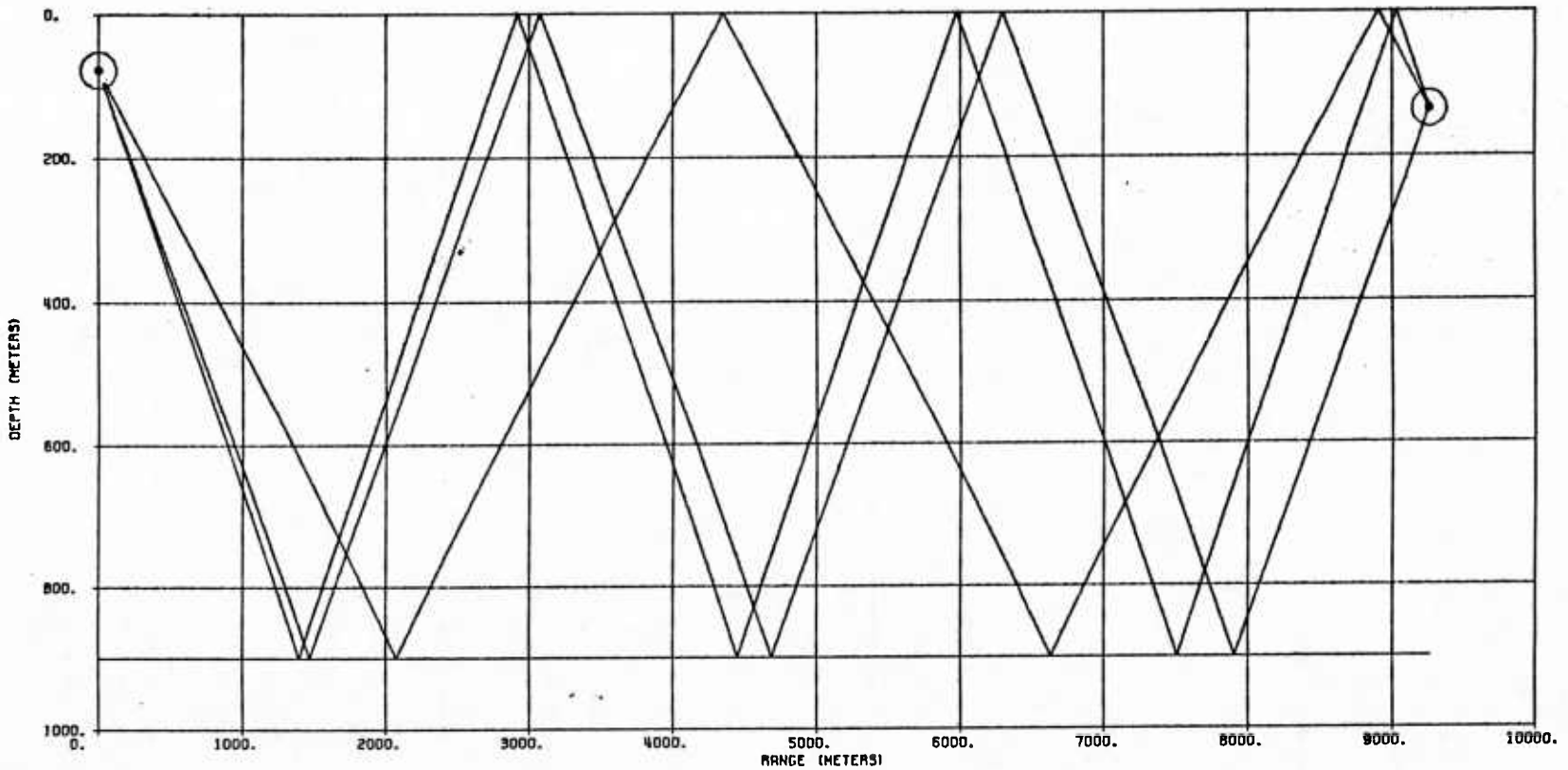


RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
36.6	-36.5	7.632	-36.6	37.8	81.15	7
37.7	37.6	7.740	-37.7	39.0	81.29	8

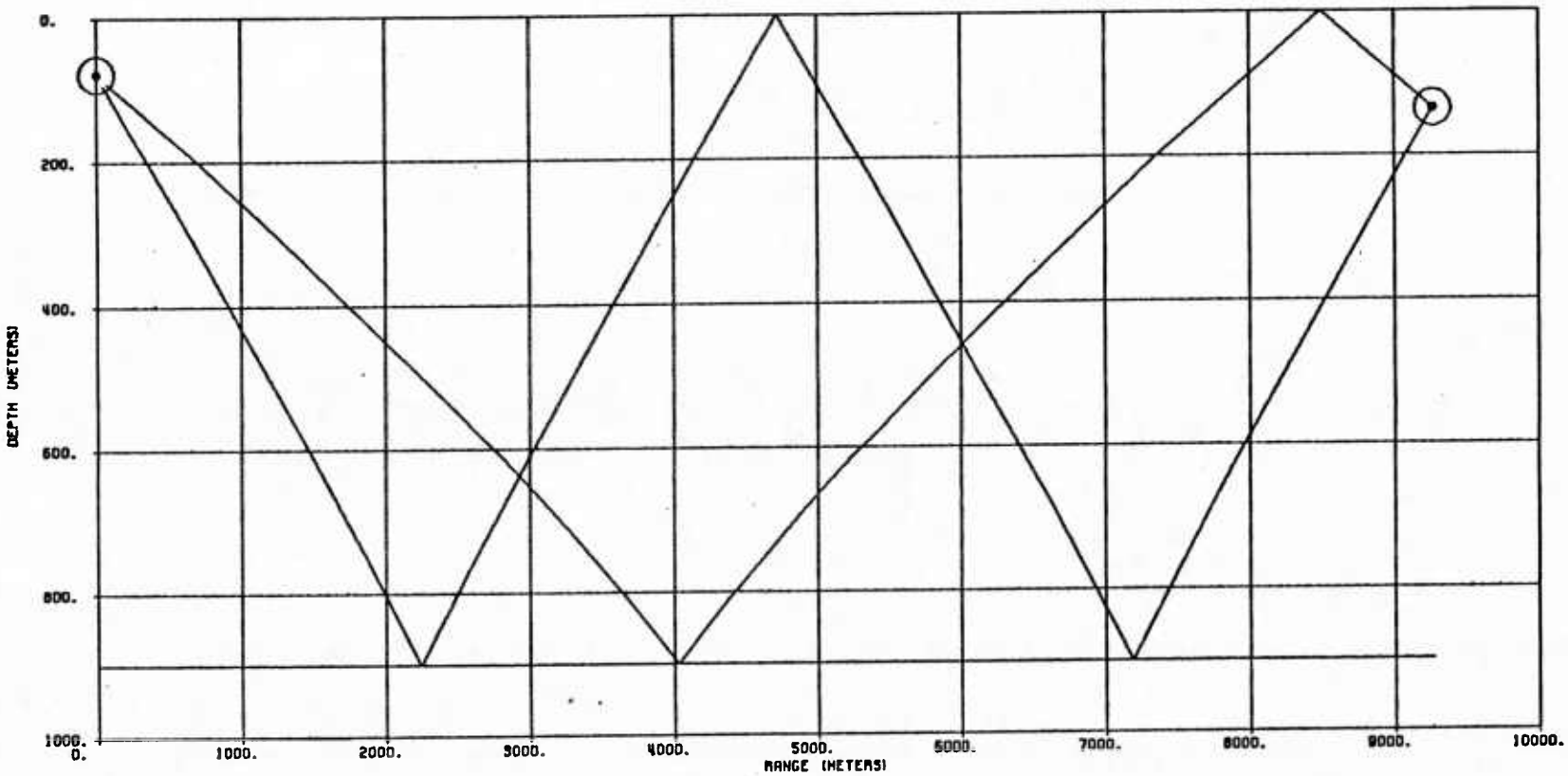


RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
20.8	20.7	6.550	-20.8	23.3	79.62	4
28.7	-28.6	6.984	-28.7	30.5	80.31	5
30.0	29.8	7.071	-30.0	31.7	80.44	6

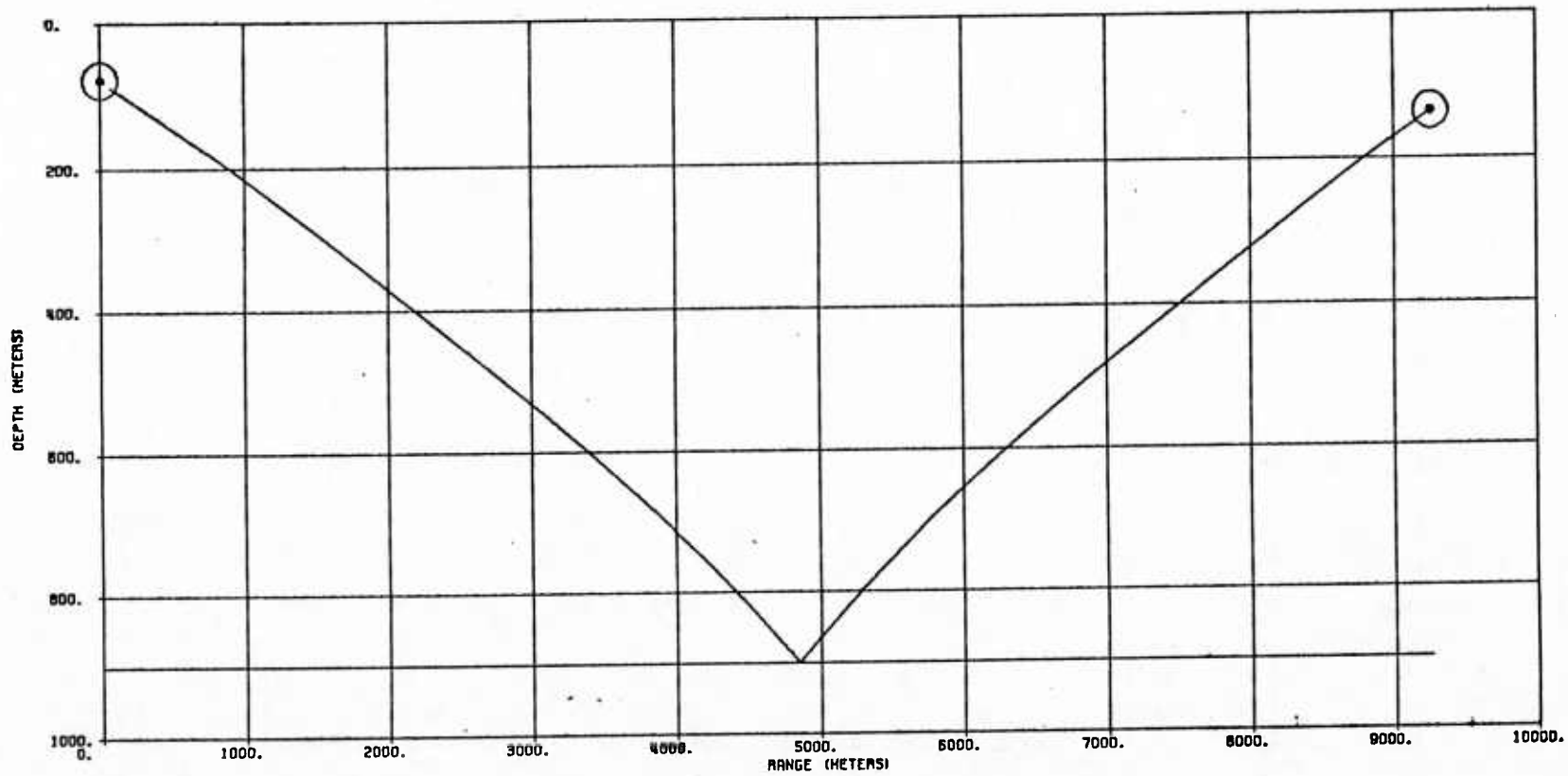


RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
10.0	9.8	6.212	-10.2	14.7	78.45	2
19.2	-19.1	6.489	-19.3	21.9	79.45	3

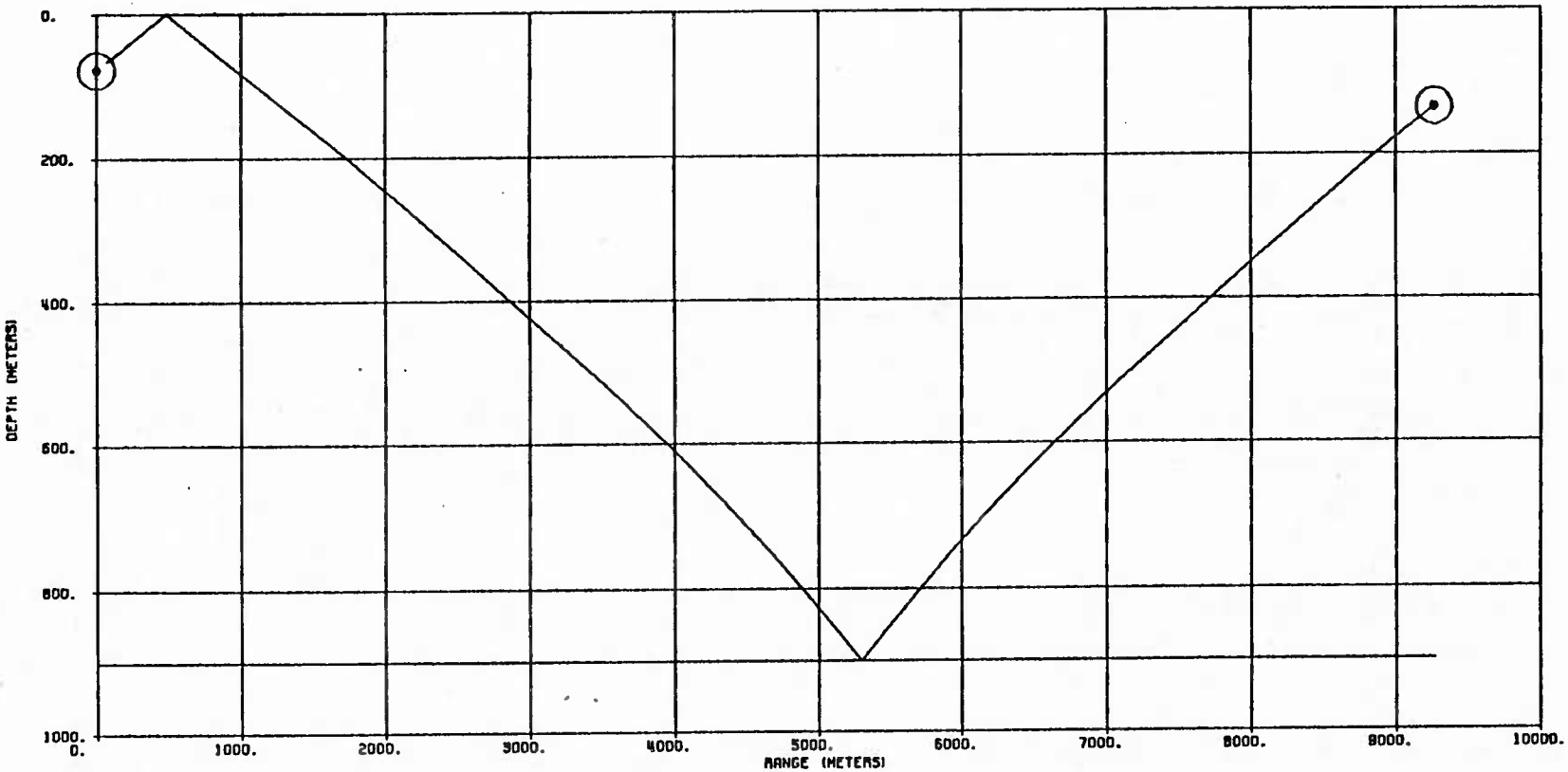


RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
7.8	-7.5	6.184	0.0	13.4	77.69	1

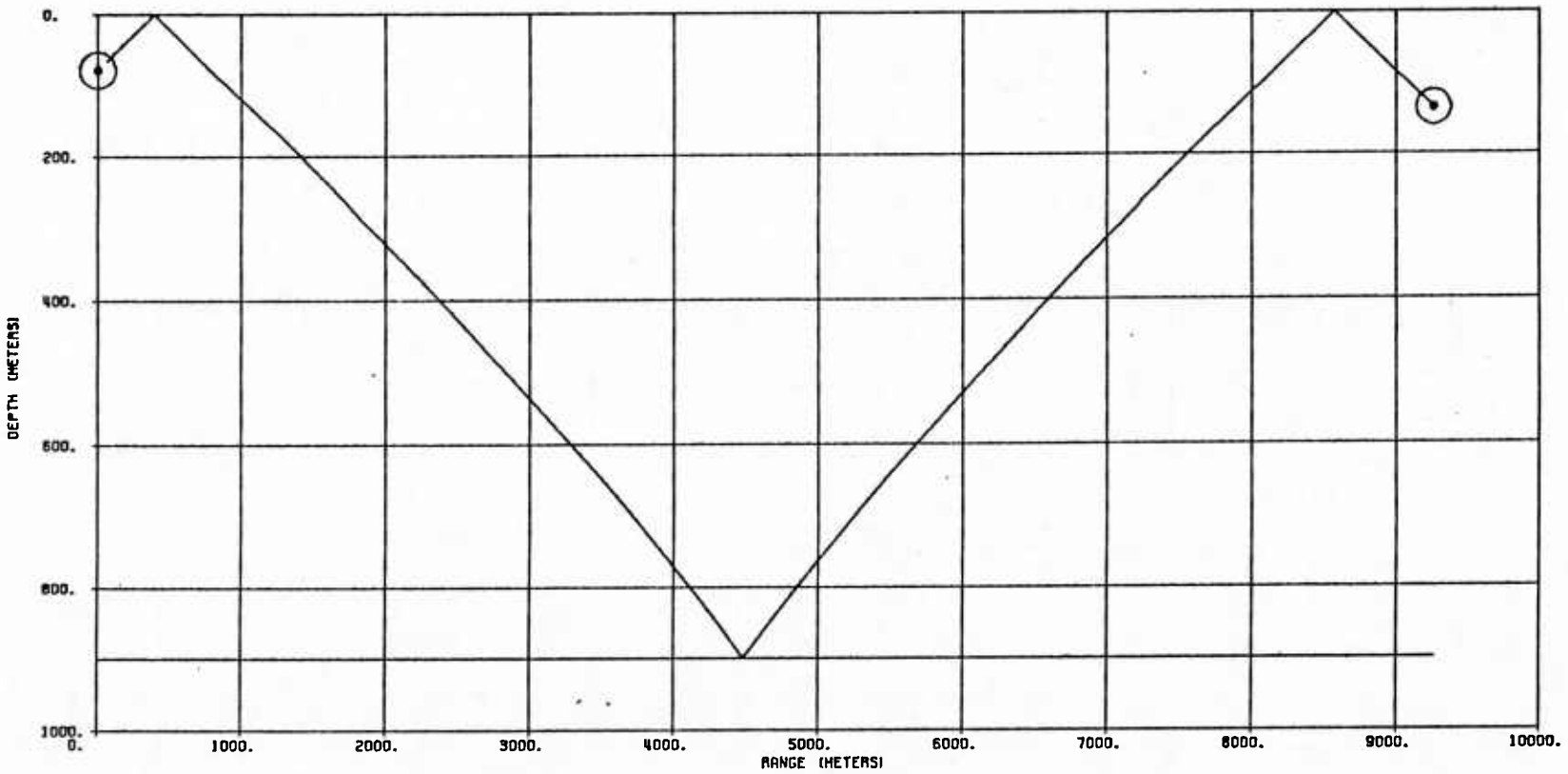


RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-9.1	-8.8	6.199	-9.3	14.1	78.18	2

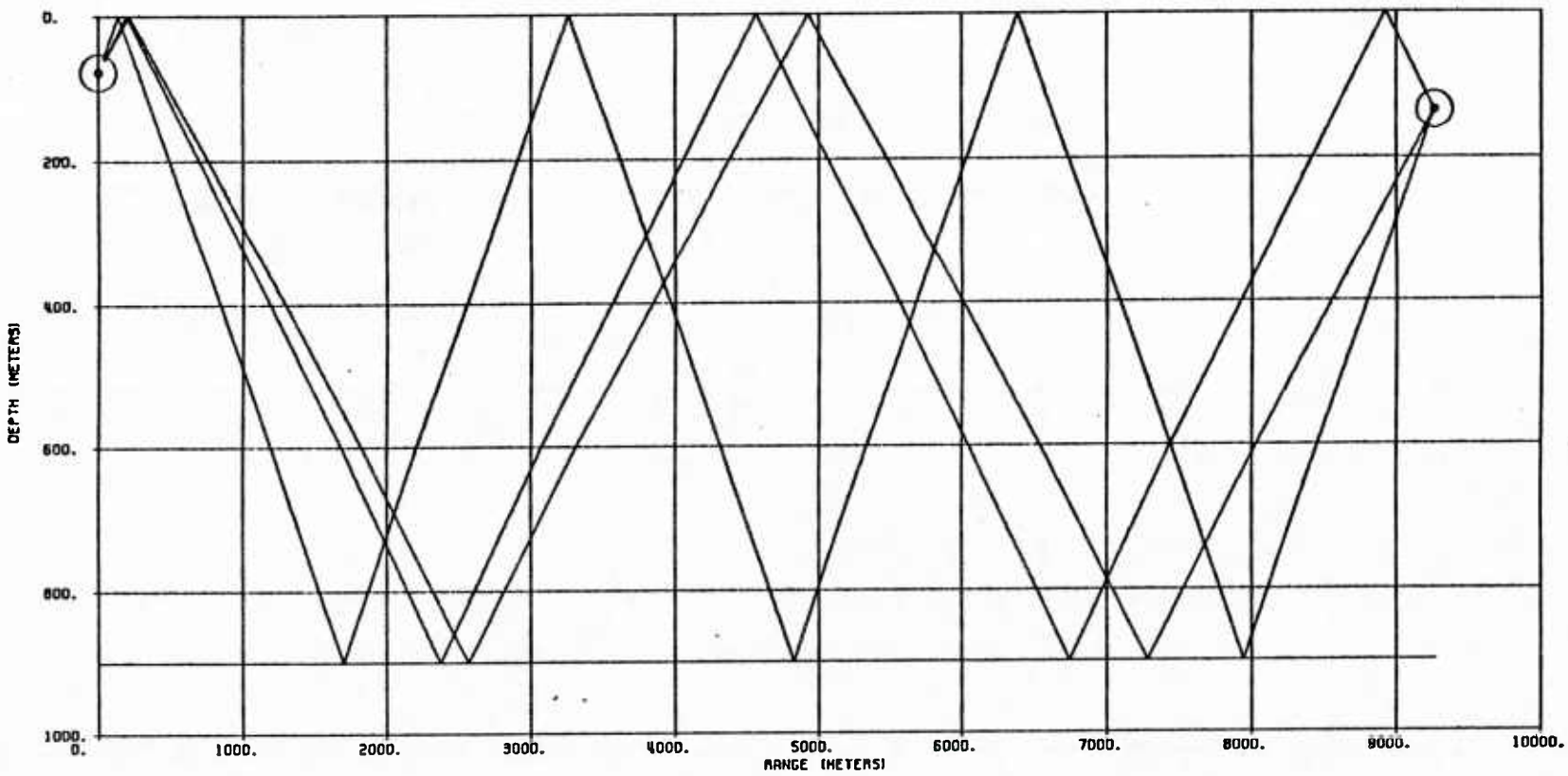


RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-11.1	10.9	6.291	-11.3	15.5	78.69	3

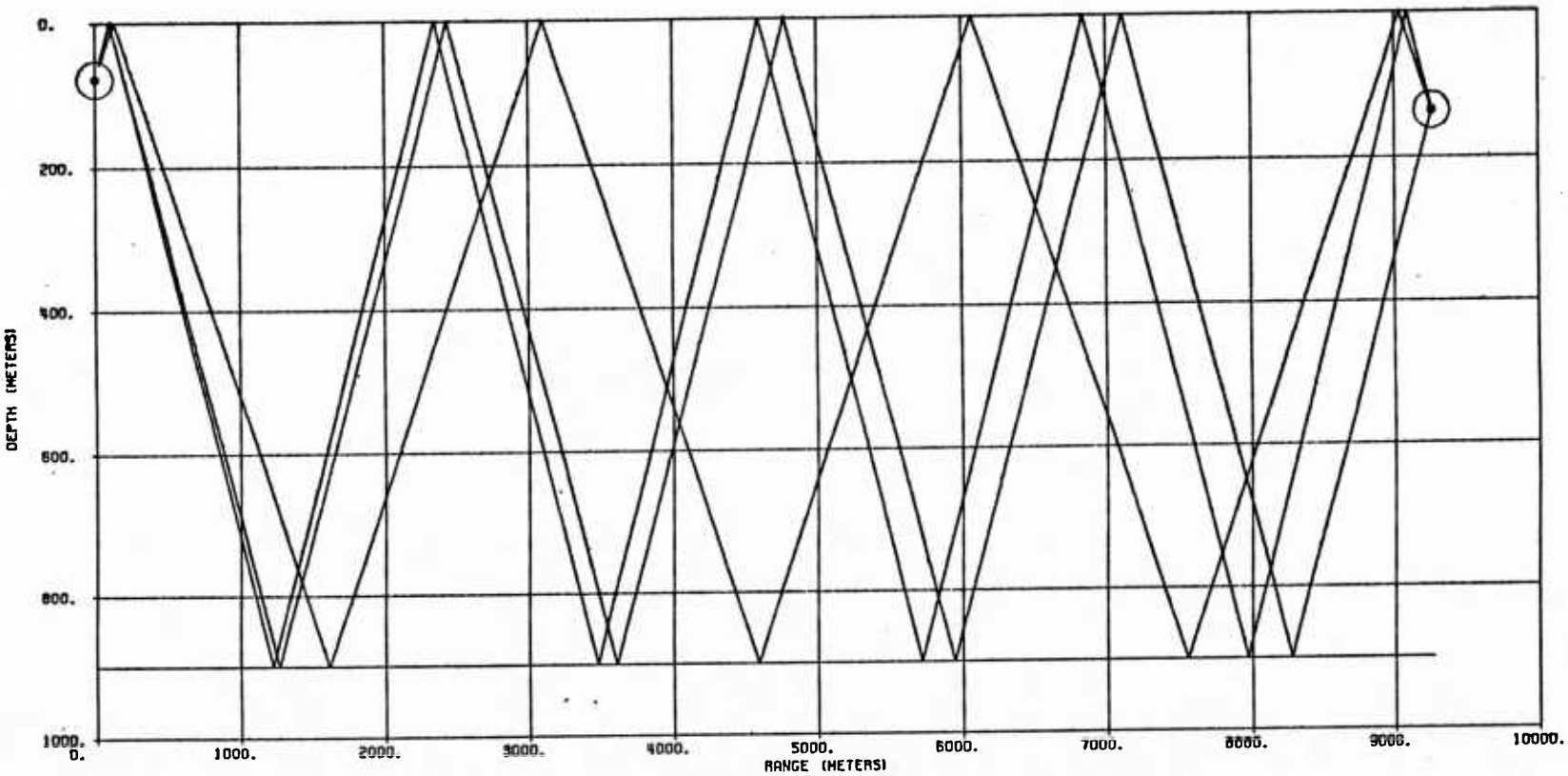


RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-20.1	-20.0	6.524	-20.2	22.7	79.55	4
-21.7	21.6	6.587	-21.8	24.1	79.70	5
-29.4	-29.3	7.034	-29.5	31.2	80.39	6



RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-30.7	30.6	7.123	-30.8	32.4	80.52	7
-37.2	-37.2	7.694	-37.3	38.5	81.23	8
-38.3	38.2	7.803	-38.3	39.6	81.36	9

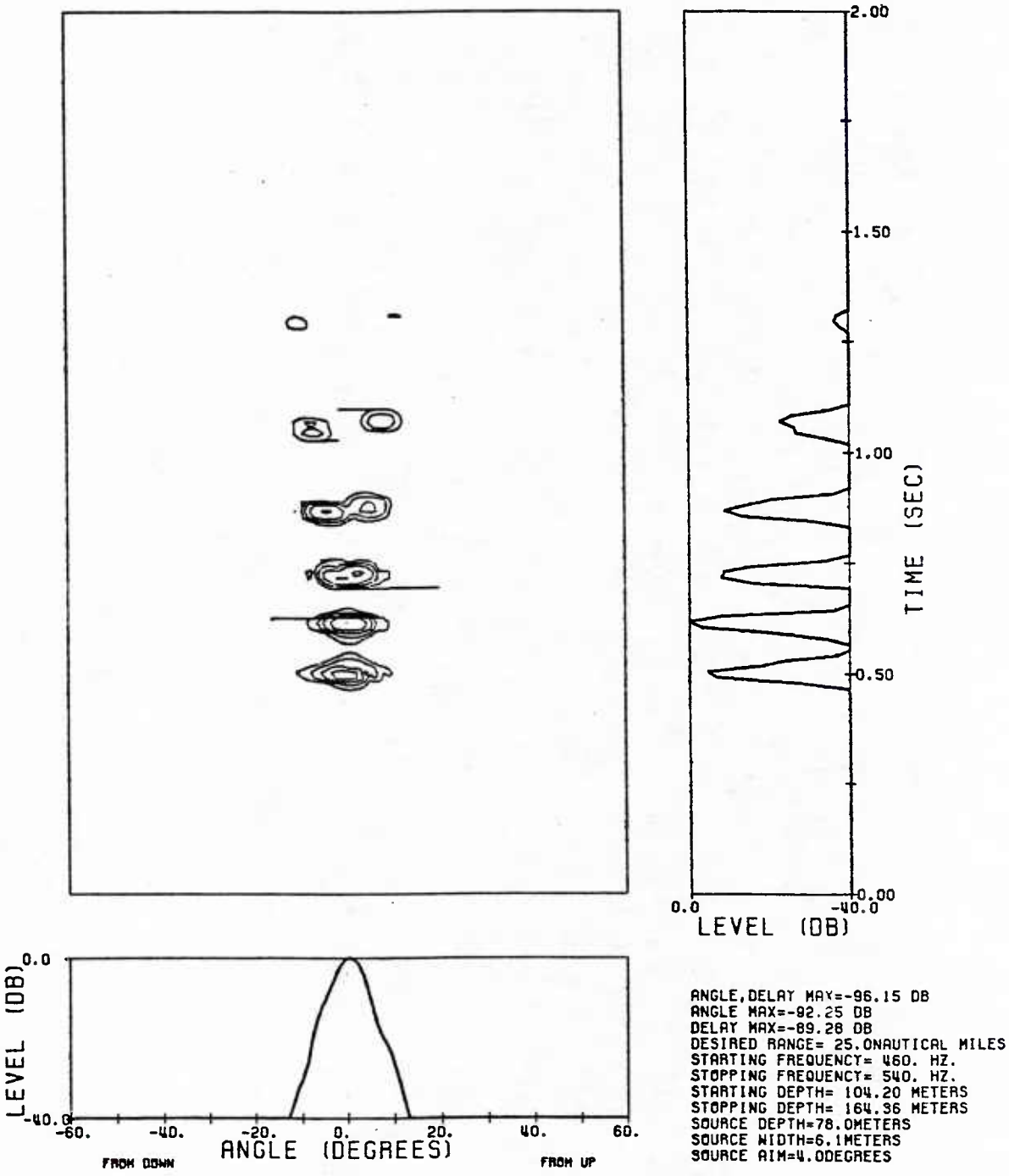
B15/B16 REVERSE BLANK

RANGE = 25 MILES

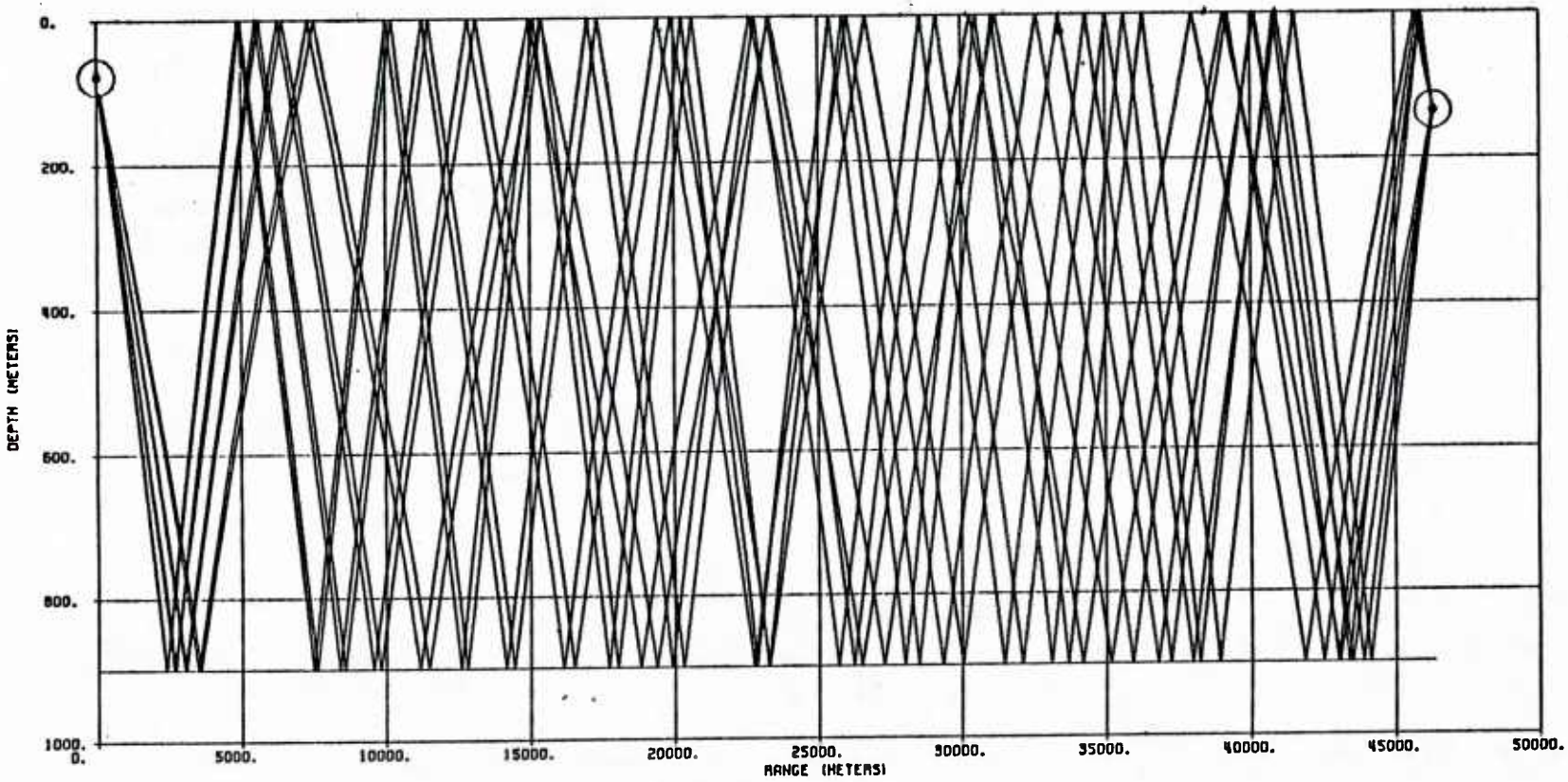
REVERSE BLANK

TM No. 811061

A17CFEB90 BLAKE



ANGLE,DELAY MAX=-96.15 DB
ANGLE MAX=-92.25 DB
DELAY MAX=-89.28 DB
DESIRED RANGE= 25.0NAUTICAL MILES
STARTING FREQUENCY= 460. HZ.
STOPPING FREQUENCY= 540. HZ.
STARTING DEPTH= 104.20 METERS
STOPPING DEPTH= 164.36 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=6.1METERS
SOURCE AIM=4.0DEGREES

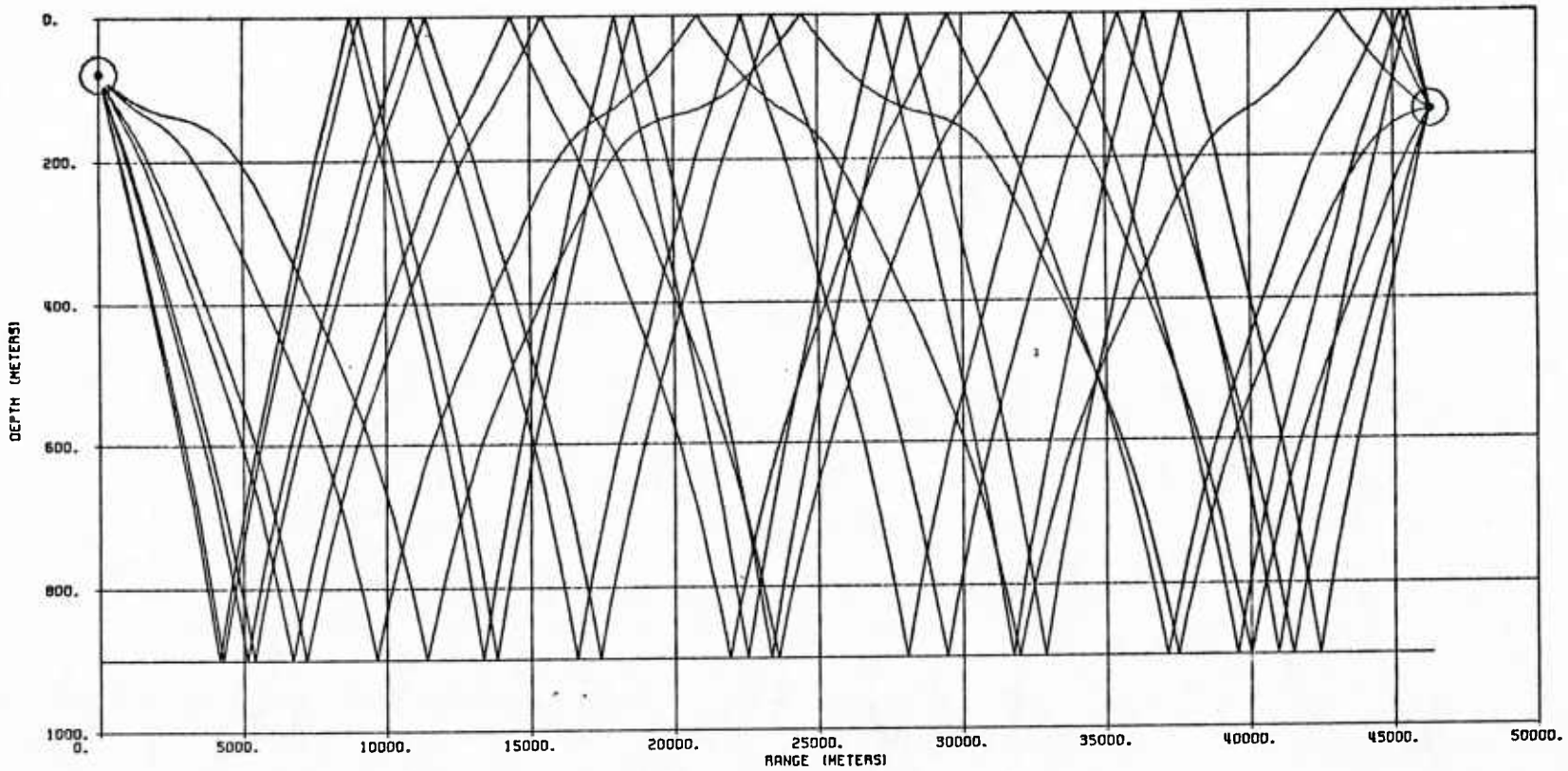


RUN FOR BT62B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
11.6	-11.4	31.249	-11.8	15.8	92.62	11
12.0	11.8	31.285	-12.1	16.1	92.70	12
13.9	-13.7	31.535	-14.0	17.5	92.92	13
14.2	14.0	31.578	-14.3	17.8	92.97	14
16.0	-15.9	31.862	-16.2	19.3	93.16	15
16.4	16.2	31.912	-16.5	19.6	93.20	16
18.2	-18.0	32.229	-18.3	21.1	93.35	17
18.5	18.4	32.285	-18.6	21.3	93.39	18

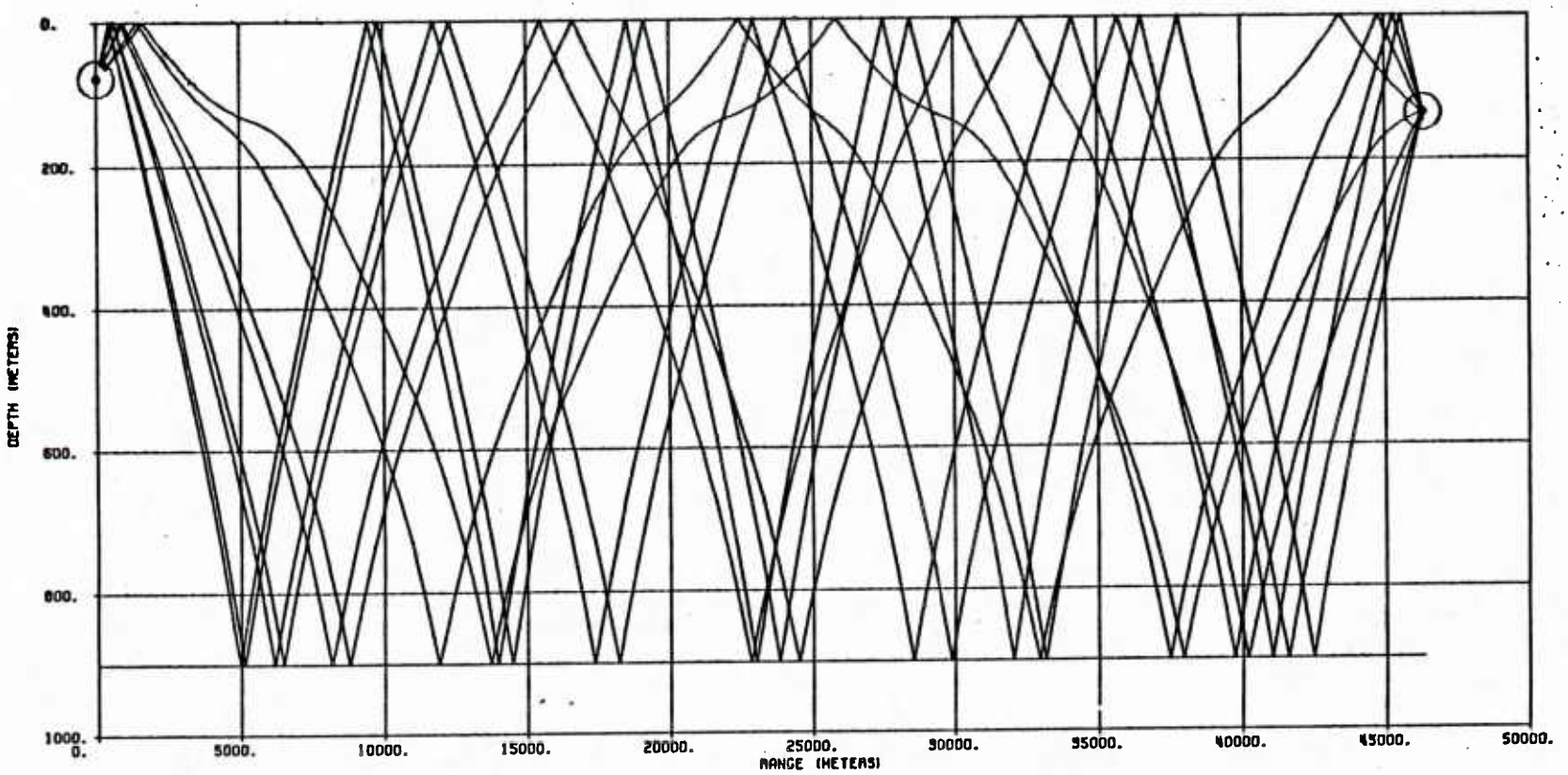


RUN FOR BT62B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.3	-0.5	30.511	-3.0	11.1	90.87	3
2.6	1.3	30.518	-3.3	11.2	89.65	4
4.2	-3.6	30.639	-4.7	11.6	90.29	5
4.8	4.2	30.653	-5.2	11.8	90.82	6
6.8	-6.4	30.802	-7.1	12.8	91.54	7
7.2	6.9	30.823	-7.5	13.0	91.77	8
9.2	-9.0	31.004	-9.4	14.2	92.21	9
9.7	9.4	31.034	-9.9	14.5	92.33	10

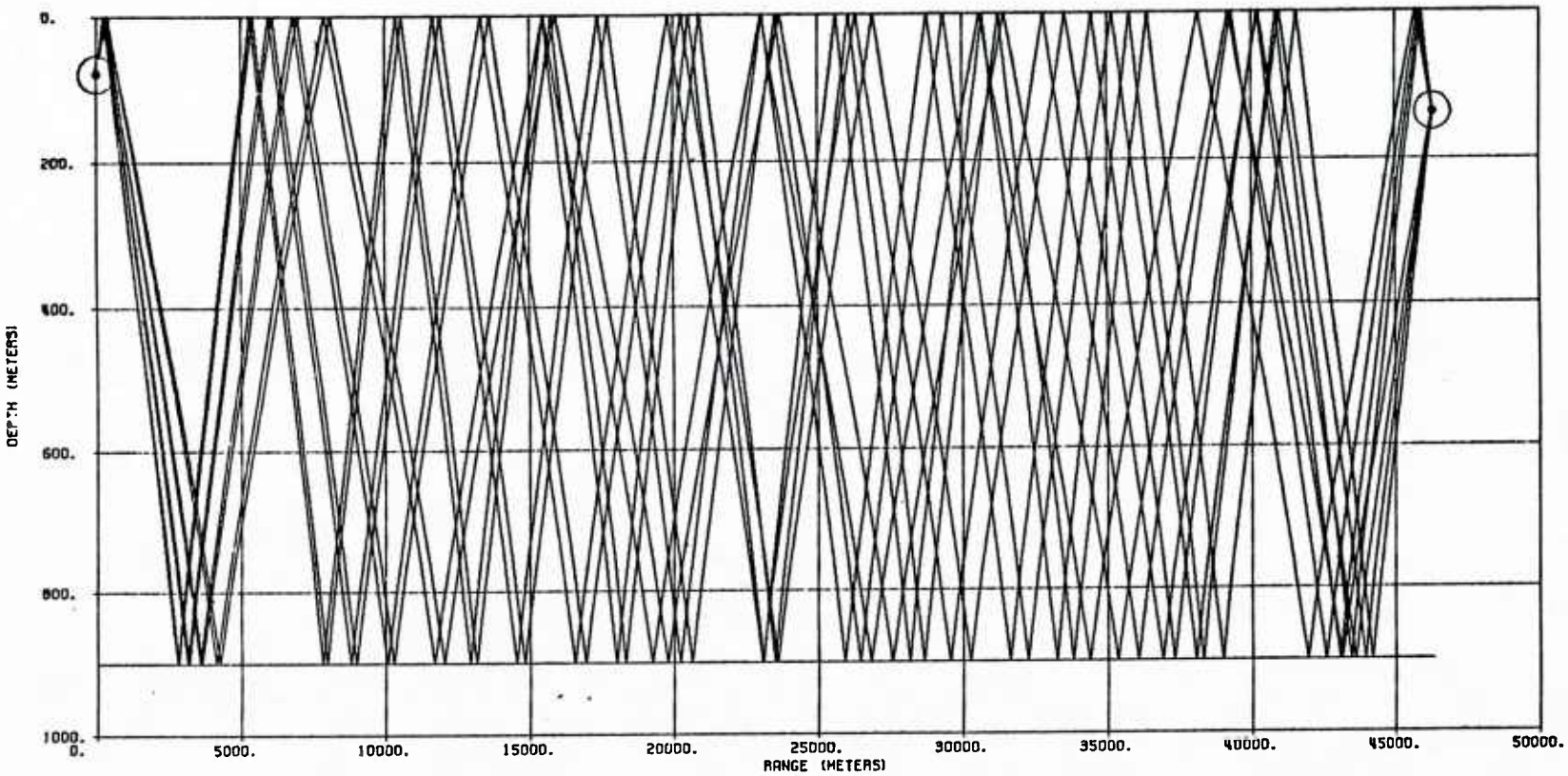


RUN FOR BT62B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.4	-0.8	30.516	-3.1	11.1	89.57	4
-2.8	1.7	30.523	-3.5	11.2	89.72	5
-4.5	-3.8	30.648	-4.9	11.8	90.56	6
-5.1	4.5	30.663	-5.4	12.0	91.03	7
-7.0	-6.7	30.814	-7.3	12.9	91.67	8
-7.5	7.2	30.837	-7.8	13.2	91.88	9
-9.5	-9.2	31.021	-9.7	14.4	92.28	10
-9.9	9.6	31.051	-10.1	14.6	92.39	11



RUN FOR BT62B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-11.8	-11.6	31.270	-12.0	16.0	92.67	12
-12.2	12.0	31.307	-12.3	16.3	92.74	13
-14.1	-13.9	31.560	-14.2	17.7	92.95	14
-14.4	14.2	31.604	-14.6	18.0	93.00	15
-16.2	-16.1	31.891	-16.4	19.4	93.18	16
-16.6	16.4	31.941	-16.7	19.7	93.22	17
-18.3	-18.2	32.261	-18.4	21.2	93.38	18
-18.7	18.5	32.318	-18.8	21.5	93.41	19

B23/B24 REVERSE BLANK

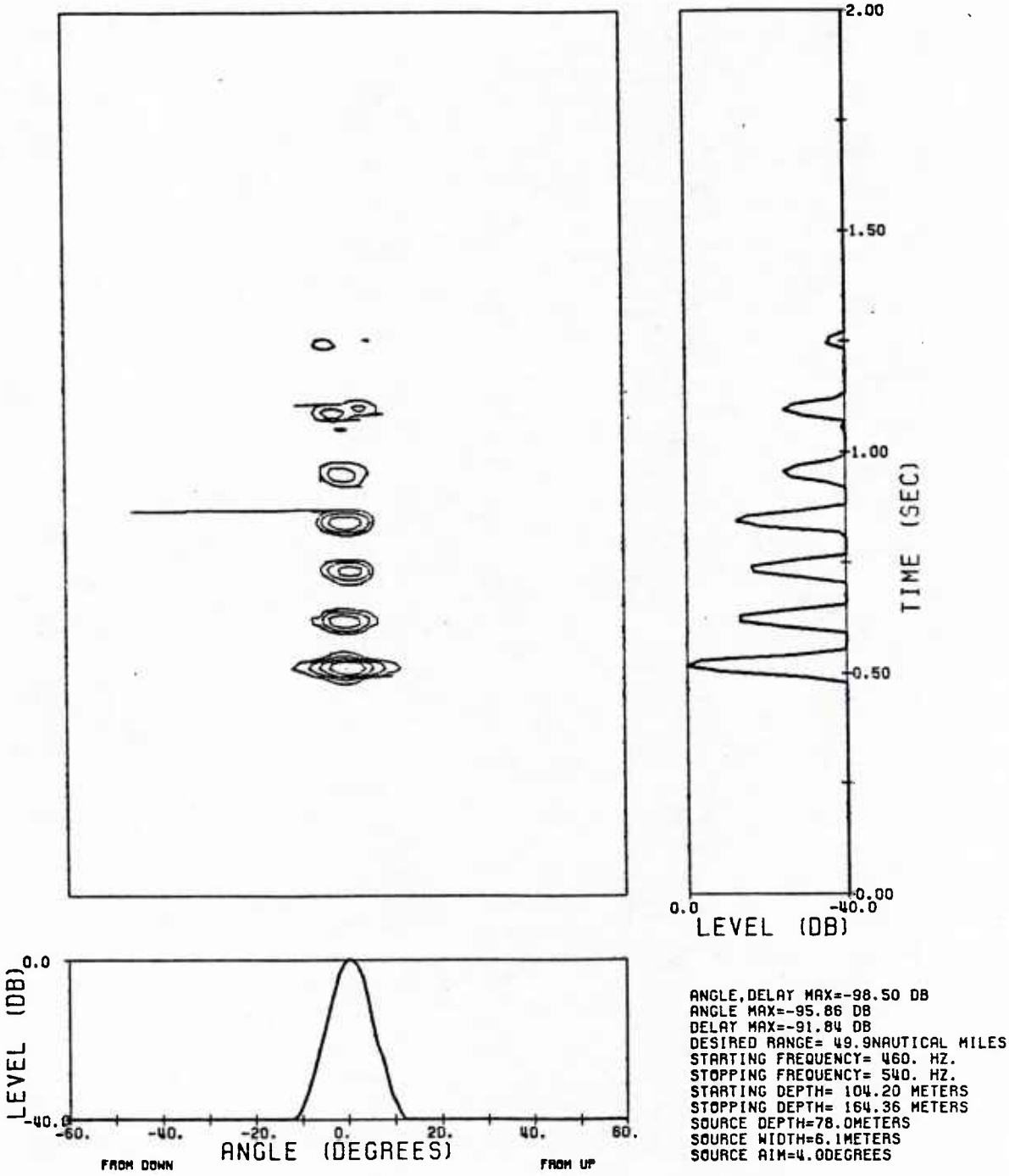
TM No. 811061

RANGE = 50 MILES

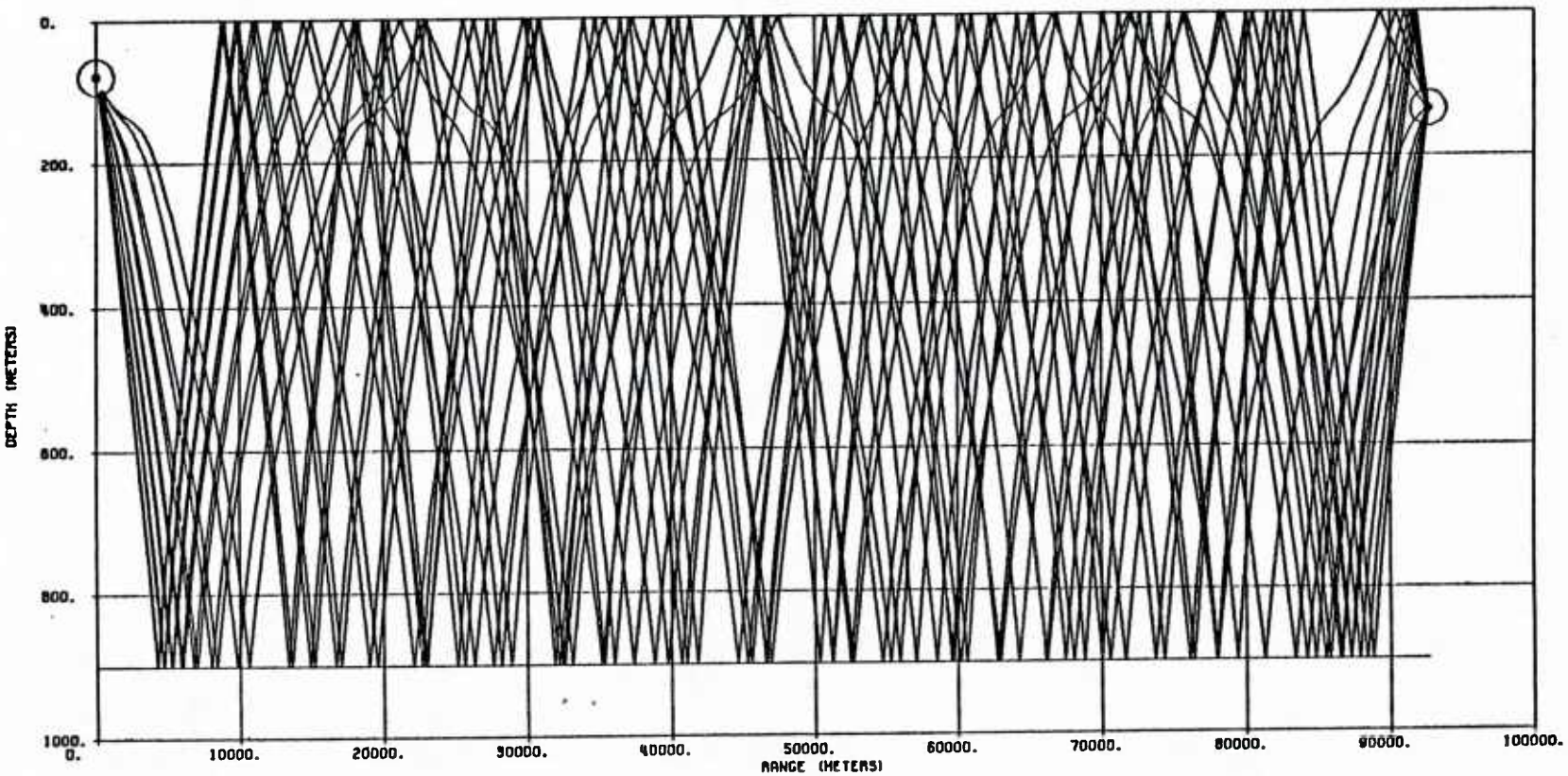
REVERSE BLANK

TM No. 811061

A17CFEB90 BLAKE



ANGLE,DELAY MAX=-98.50 DB
ANGLE MAX=-95.86 DB
DELAY MAX=-91.84 DB
DESIRED RANGE= 49.9NAUTICAL MILES
STARTING FREQUENCY= 460. HZ.
STOPPING FREQUENCY= 540. HZ.
STARTING DEPTH= 104.20 METERS
STOPPING DEPTH= 164.36 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=6.1METERS
SOURCE AIM=4.0DEGREES

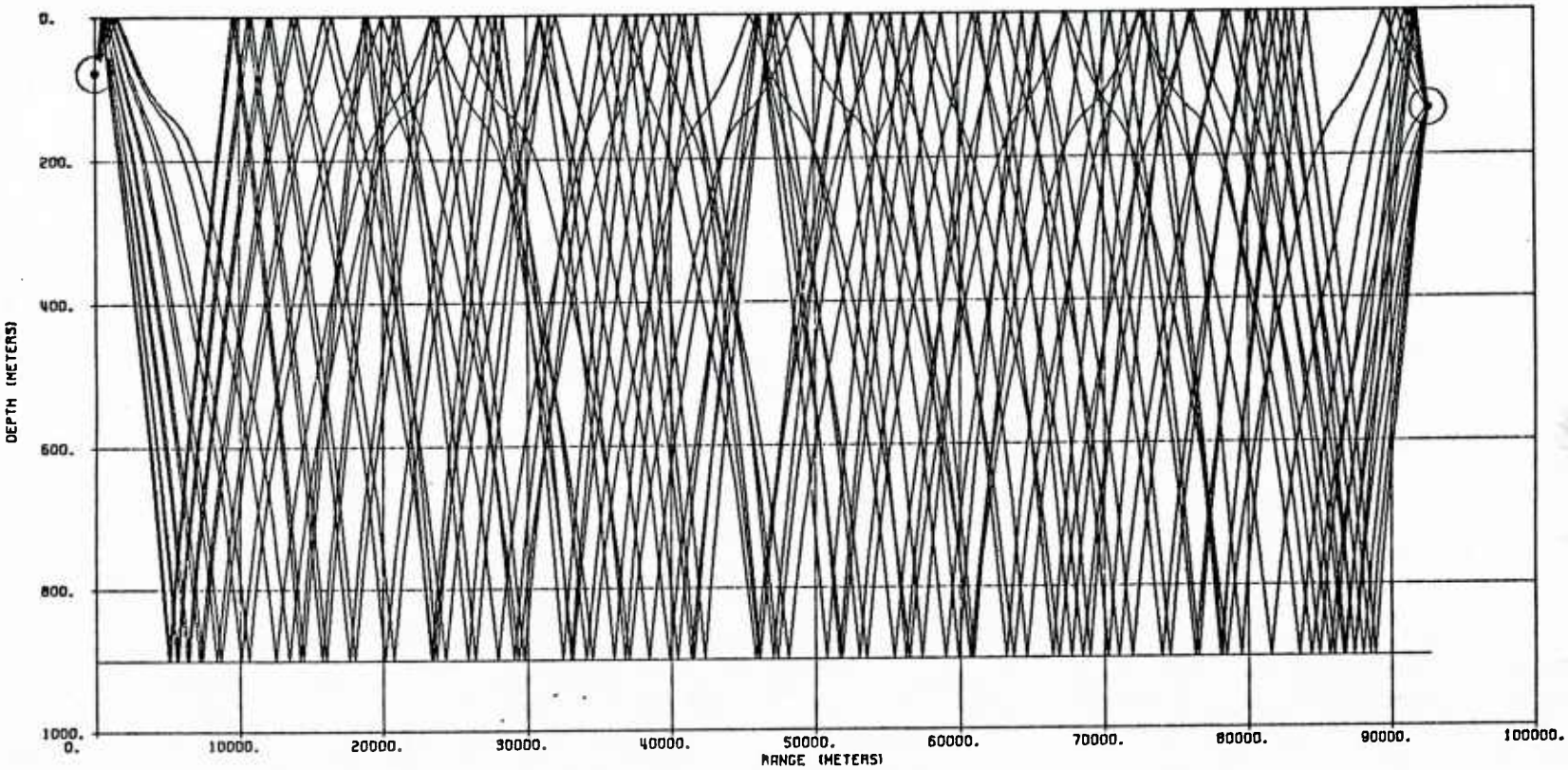


RUN FOR BT61B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.4	-0.8	61.027	-3.1	11.1	95.99	7	6.0	5.5	61.463	-6.3	12.4	97.36	14
2.5	1.2	61.035	-3.2	11.1	95.76	8	7.0	-6.6	61.620	-7.2	12.8	97.66	15
3.2	-2.3	61.152	-3.8	11.3	95.67	9	7.2	6.8	61.642	-7.5	13.0	97.77	16
3.5	2.7	61.162	-4.0	11.4	96.07	10	8.2	-7.9	61.816	-8.4	13.6	98.01	17
4.4	-3.8	61.290	-4.9	11.7	96.55	11	8.4	8.1	61.841	-8.6	13.7	98.09	18
4.7	4.1	61.304	-5.1	11.8	96.79	12	9.4	-9.1	62.032	-9.6	14.3	98.29	19
5.7	-5.3	61.445	-6.0	12.3	97.18	13	9.6	9.3	62.061	-9.8	14.5	98.34	20



RUN FOR BT61B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

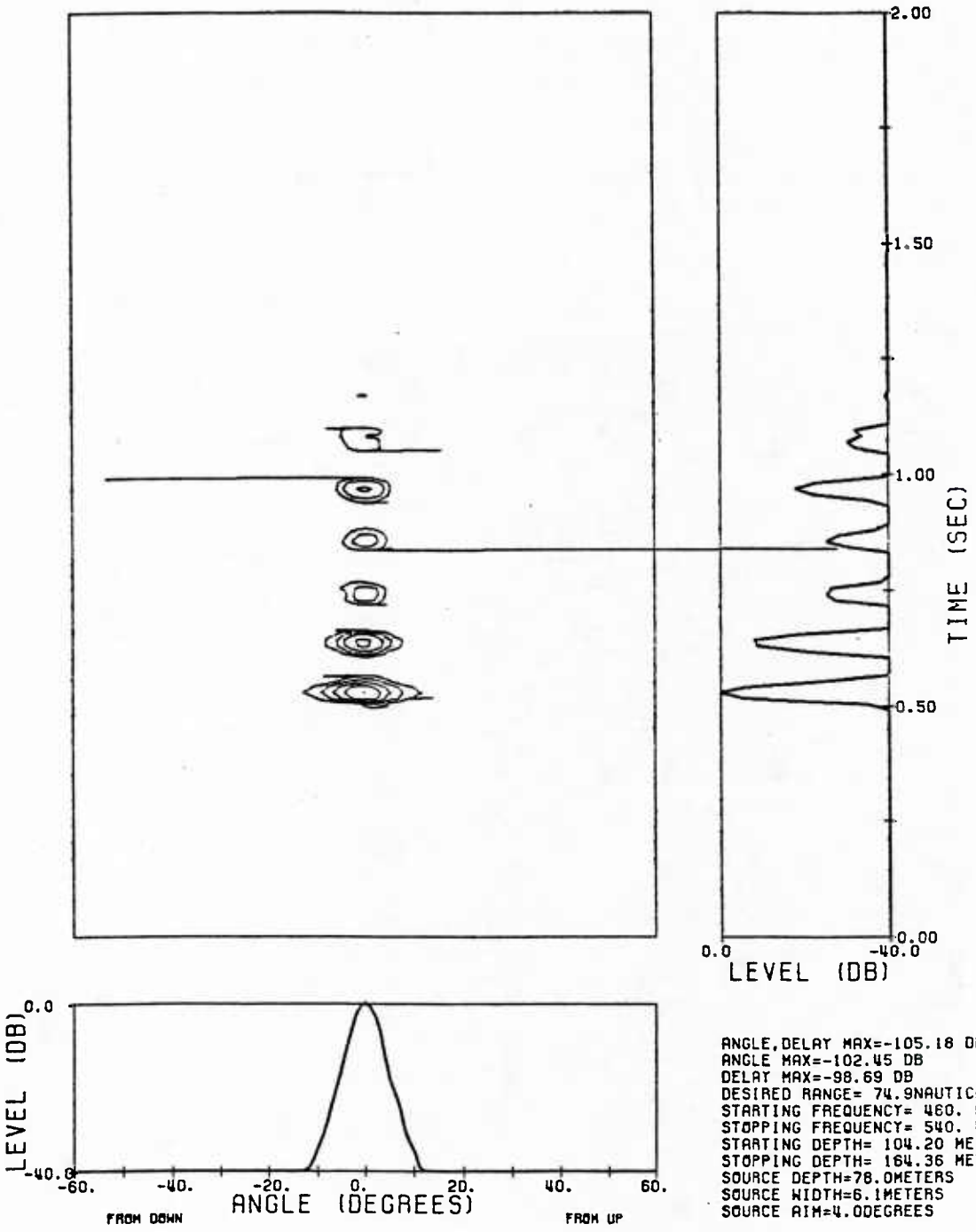
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.4	-1.0	61.032	-3.1	11.1	95.55	8	-6.1	5.7	61.475	-6.4	12.4	97.44	15
-2.6	1.4	61.040	-3.3	11.2	95.59	9	-7.1	-6.7	61.633	-7.4	12.9	97.73	16
-3.4	-2.5	61.158	-3.9	11.4	95.83	10	-7.3	7.0	61.655	-7.6	13.1	97.84	17
-3.7	2.9	61.169	-4.2	11.4	96.22	11	-8.3	-8.0	61.831	-8.6	13.6	98.05	18
-4.6	-4.0	61.298	-5.0	11.8	96.65	12	-8.5	8.2	61.857	-8.8	13.8	98.14	19
-4.9	4.3	61.313	-5.3	11.9	96.90	13	-9.5	-9.3	62.049	-9.7	14.4	98.31	20
-5.8	-5.4	61.456	-6.2	12.3	97.27	14	-9.7	9.5	62.078	-9.9	14.5	98.38	21

RANGE = 75 MILES

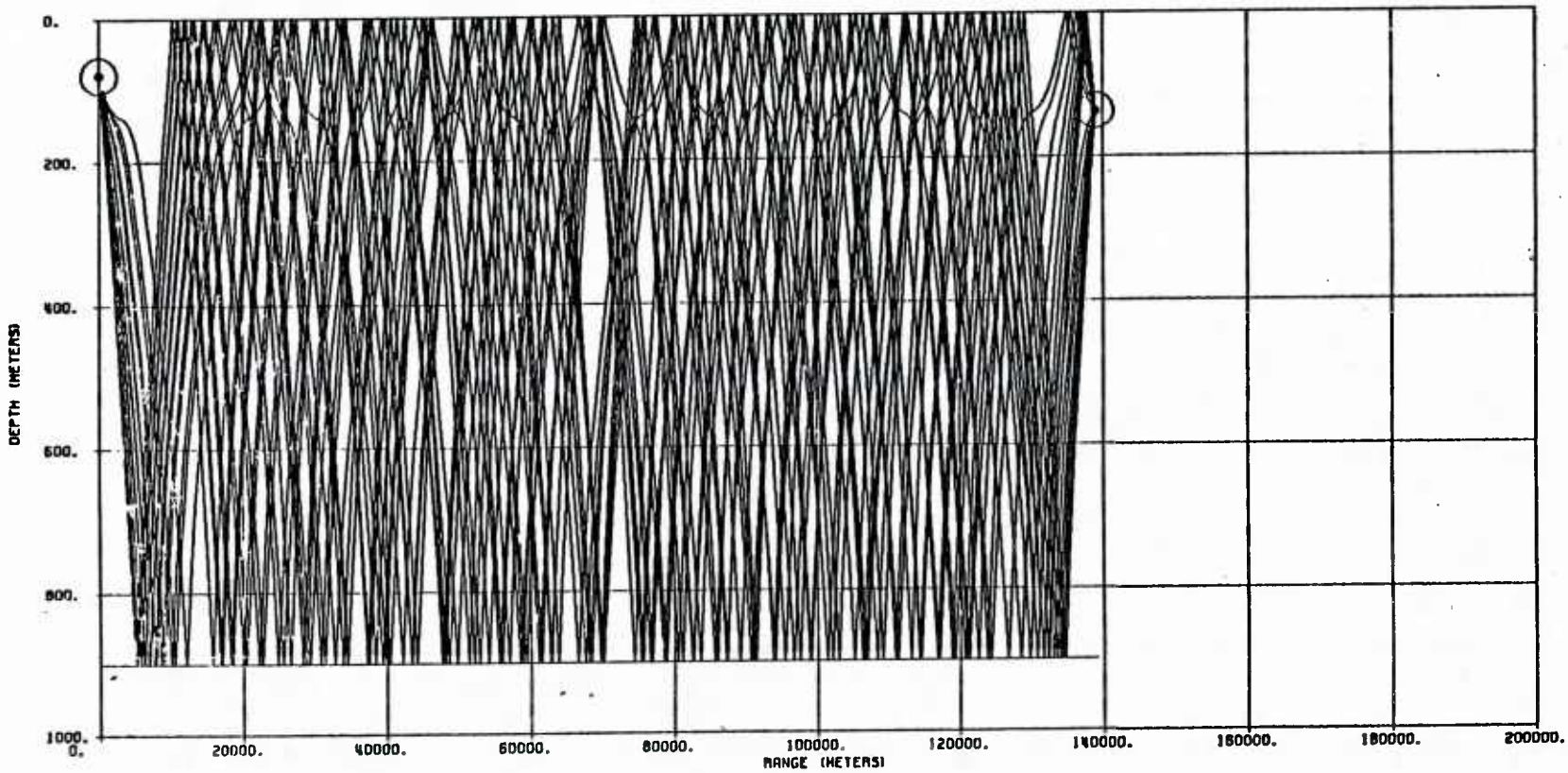
REVERSE BLANK

TM No. 811061

A17CFEB90 BLAKE



ANGLE,DELAY MAX=-105.18 DB
ANGLE MAX=-102.45 DB
DELAY MAX=-98.69 DB
DESIRED RANGE= 74.9NAUTICAL MILES
STARTING FREQUENCY= 460. HZ.
STOPPING FREQUENCY= 540. HZ.
STARTING DEPTH= 104.20 METERS
STOPPING DEPTH= 164.36 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=6.1METERS
SOURCE AIM=4.0DEGREES

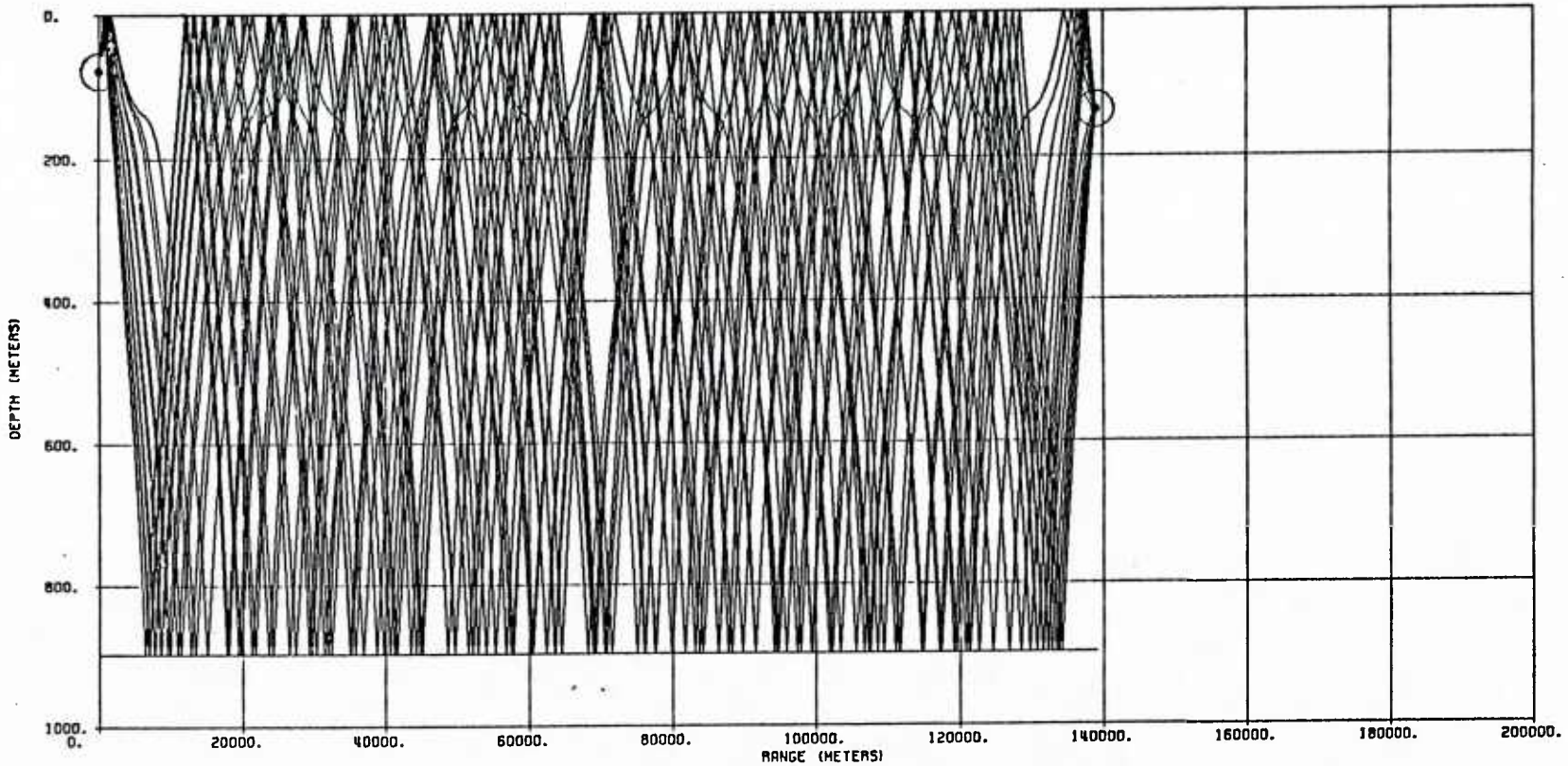


RUN FOR BT60B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.3	0.3	91.431	-3.0	11.1	106.59	10	4.7	4.1	91.955	-5.1	11.6	100.30	18
2.4	-0.9	91.544	-3.1	11.1	99.74	11	5.4	-4.9	92.094	-5.7	12.1	100.57	19
2.5	1.2	91.551	-3.2	11.1	99.32	12	5.5	5.1	92.111	-5.8	12.2	100.69	20
2.9	-1.9	91.667	-3.5	11.2	99.04	13	6.2	-5.8	92.260	-6.5	12.5	100.93	21
3.1	2.2	91.677	-3.7	11.3	99.96	14	6.4	5.9	92.279	-6.7	12.6	101.02	22
3.7	-2.9	91.799	-4.2	11.5	99.60	15	7.0	-6.7	92.438	-7.9	12.9	101.21	23
3.9	3.2	91.810	-4.4	11.5	99.82	16	7.2	6.8	92.461	-7.4	13.0	101.30	24
4.5	-3.9	91.940	-4.9	11.7	100.15	17	7.8	-7.5	92.632	-8.1	13.4	101.45	25



RUN FOR BT60B

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.3	0.4	91.436	-3.0	11.1	106.45	11	-4.6	-4.0	91.949	-5.0	11.8	100.21	18
-2.5	-1.0	91.549	-3.2	11.1	99.10	12	-4.8	4.2	91.963	-5.2	11.9	100.37	19
-2.6	1.3	91.557	-3.3	11.2	99.19	13	-5.4	-5.0	92.104	-5.8	12.1	100.63	20
-3.0	-2.0	91.673	-3.6	11.3	99.14	14	-5.6	5.2	92.121	-6.0	12.2	100.76	21
-3.2	2.3	91.683	-3.8	11.3	99.43	15	-6.3	-5.9	92.271	-6.6	12.5	101.00	22
-3.8	-3.1	91.806	-4.3	11.5	99.69	16	-6.4	6.0	92.291	-6.7	12.6	101.09	23
-4.0	3.3	91.818	-4.4	11.6	99.93	17	-7.1	-6.8	92.452	-7.4	13.0	101.26	24
							-7.3	6.9	92.474	-7.5	13.0	101.34	25

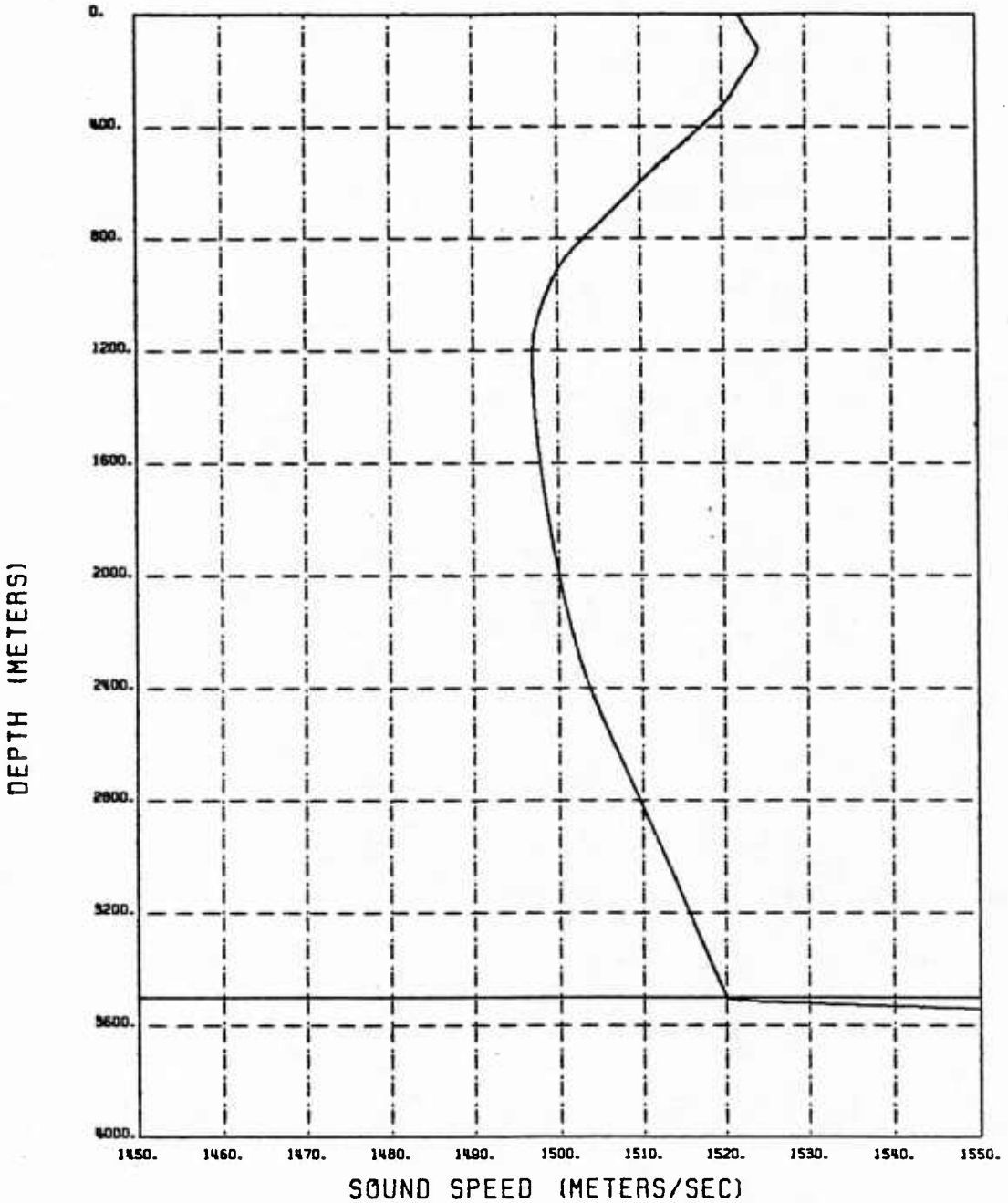
B35/B36 REVERSE BLANK

TM No. 811061

APPENDIX C

MID-ATLANTIC RIDGE PE & RAY TRACING RESULTS (MARCH PROFILE)

REVERSE BLANK

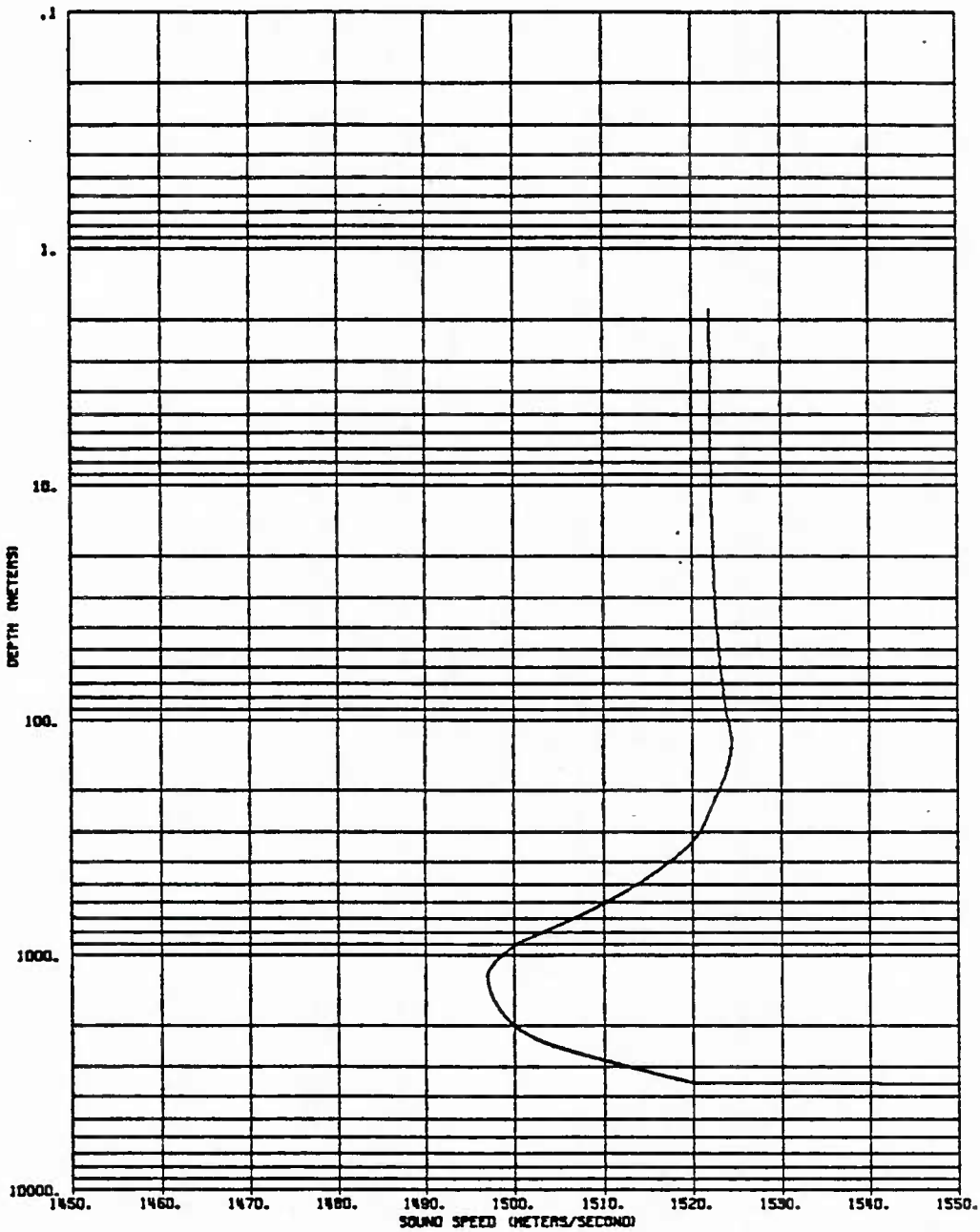


FREQUENCY = 495.0 HZ

SOURCE DEPTH = 78.0 METERS
SOURCE AIM = 15.0 DEGREES
SOURCE WIDTH = 10.0 METERS

PROBLEM DEPTH = 3700.0 METERS
BOTTOM DEPTH = 3501.3 METERS
VERTICAL MESH SPACING = 1.81 METERS
BOTTOM ATTENUATION CONSTANT = 0.001000
ATTENUATION SCALE LENGTH = 500.0
SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 216875. METERS
RANGE MESH SPACING = 62.50 METERS



E11MAR35 RIDGE

FREQUENCY = 495.0 HZ

SOURCE DEPTH = 78.0 METERS
SOURCE AIM = 15.0 DEGREES
SOURCE WIDTH = 10.0 METERS

PROBLEM DEPTH = 3700.0 METERS
BOTTOM DEPTH = 3501.3 METERS
VERTICAL MESH SPACING = 1.81 METERS
BOTTOM ATTENUATION CONSTANT = 0.001000
ATTENUATION SCALE LENGTH = 500.0
SVP TRANSITION REGION=500.0 METERS

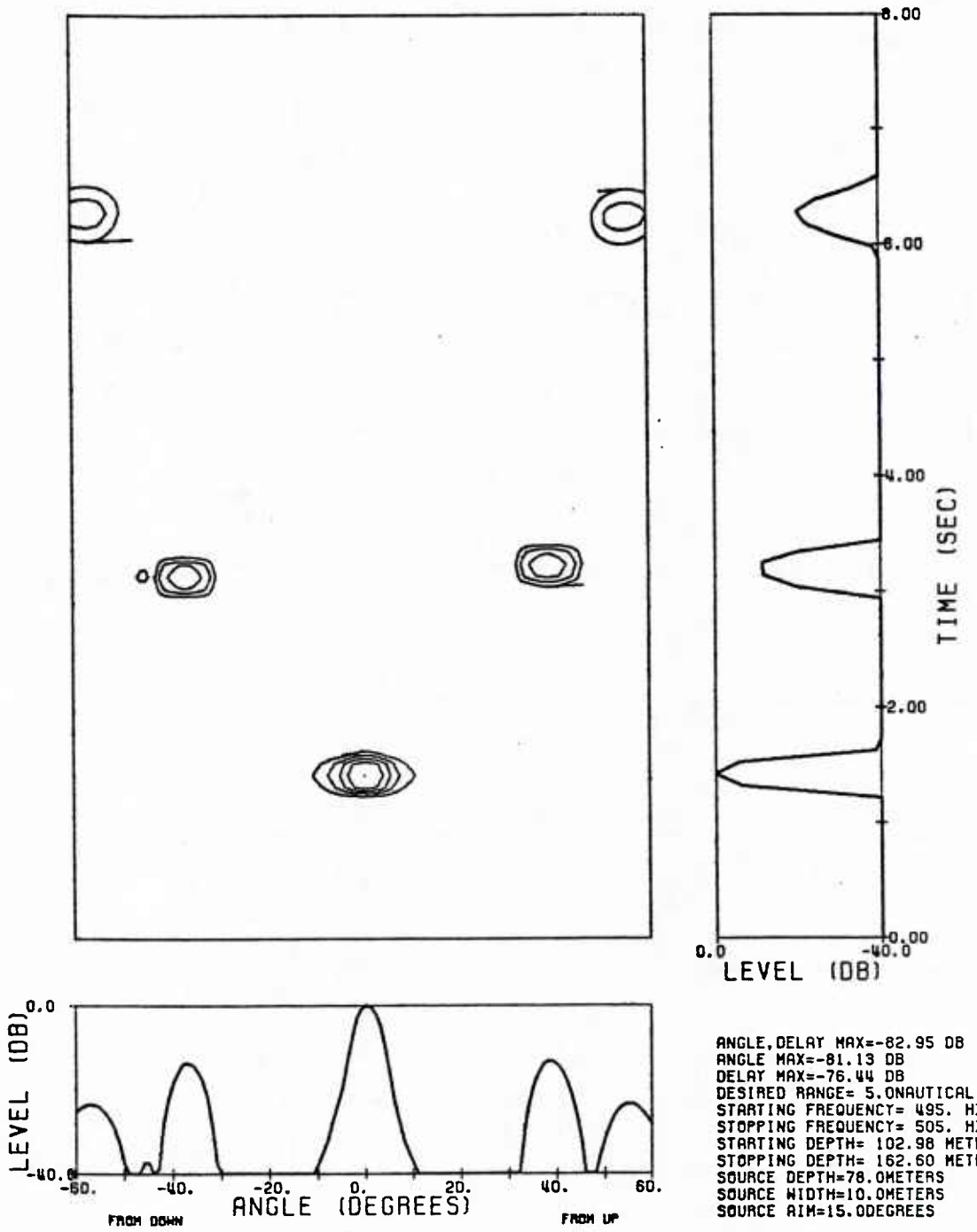
PROBLEM RANGE = 216875. METERS
RANGE MESH SPACING = 62.50 METERS

RANGE = 5 MILES

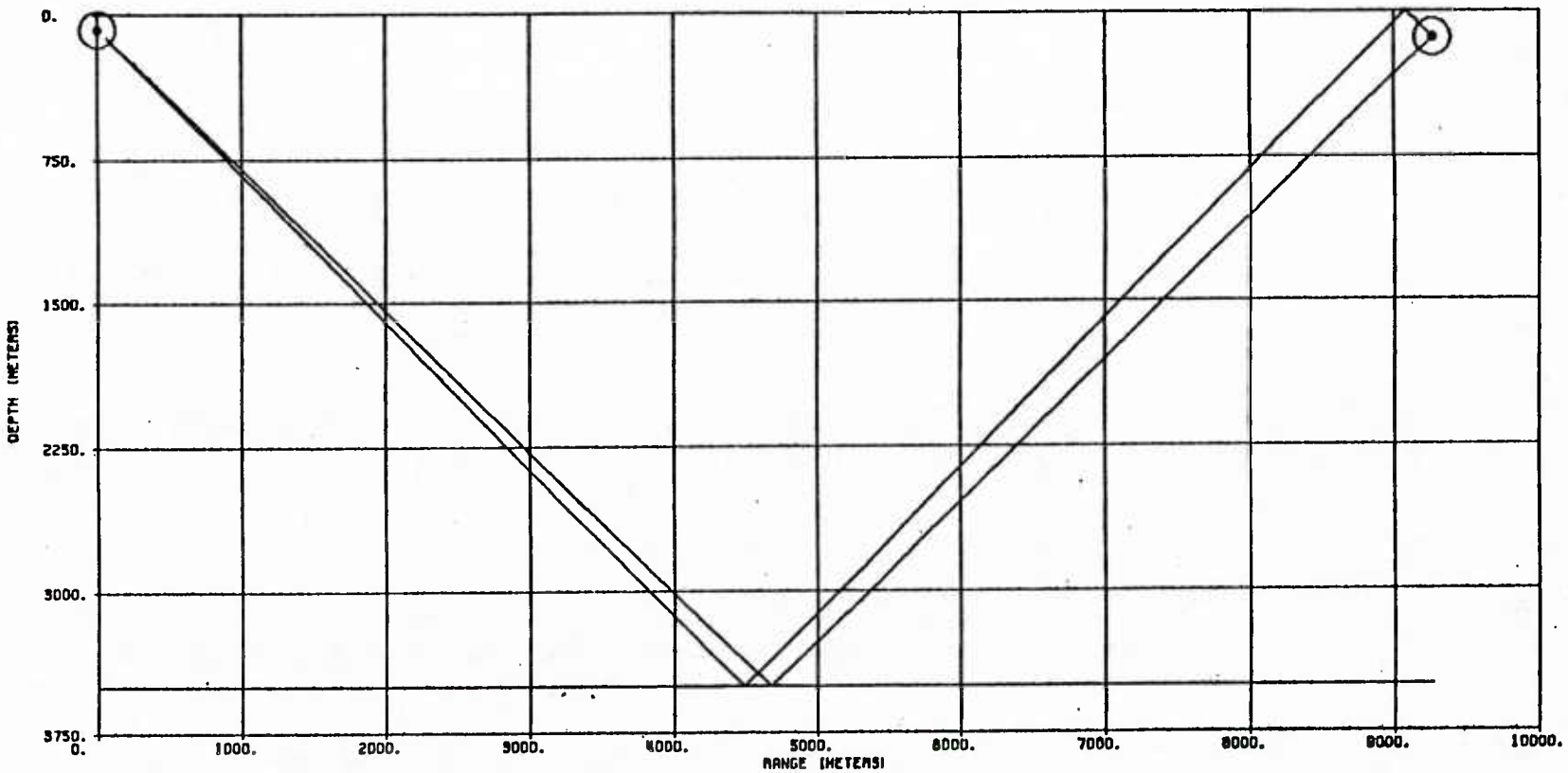
REVERSE BLANK

TM No. 811061

E11MAR35 RIDGE



ANGLE,DELAY MAX=-82.95 DB
ANGLE MAX=-81.13 DB
DELAY MAX=-76.44 DB
DESIRED RANGE= 5.0NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=15.0DEGREES

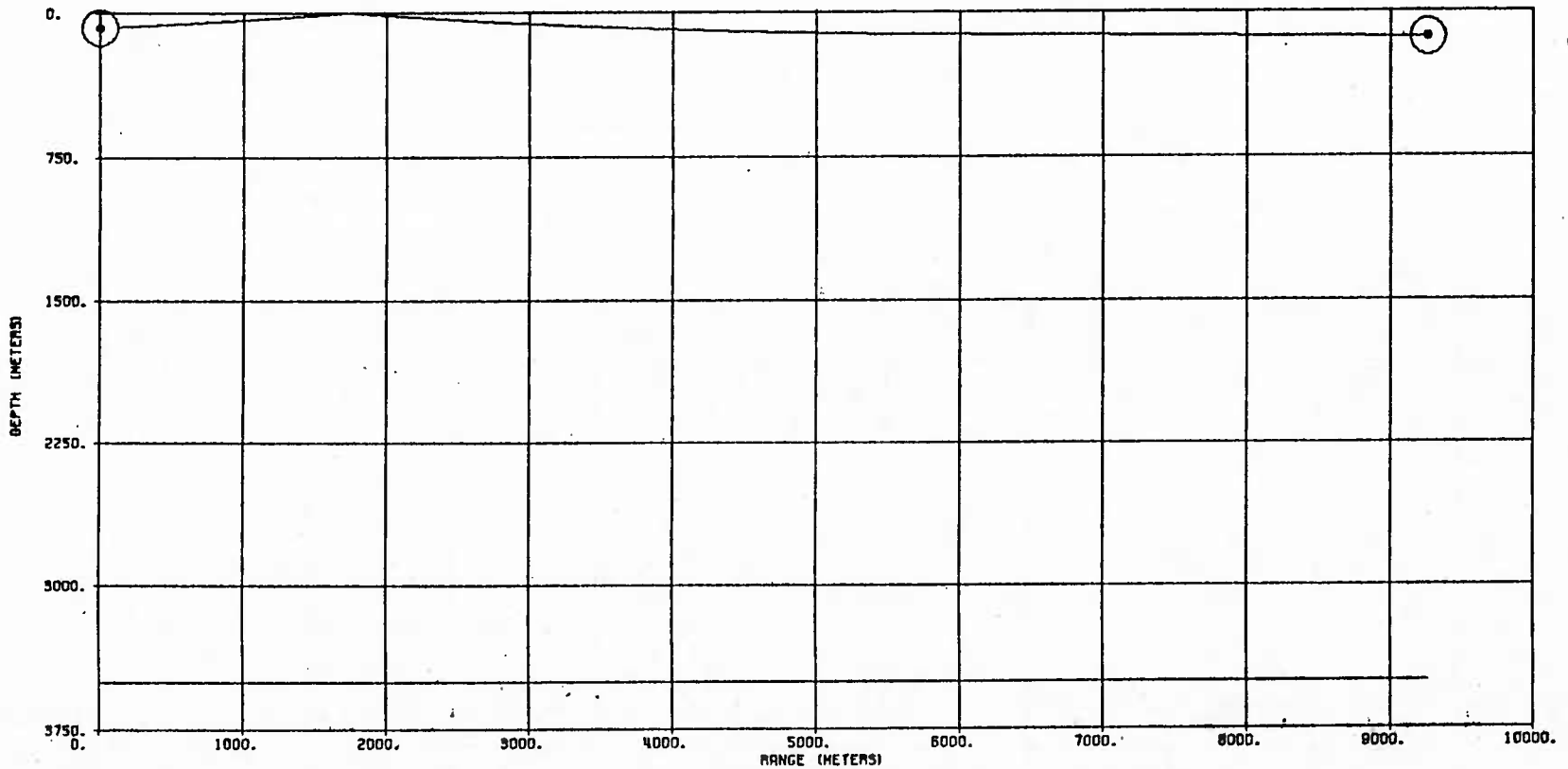


RUN FOR BT57C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
35.3	-35.3	7.624	0.0	35.5	80.81	1
36.5	36.4	7.729	-36.6	36.7	81.06	2

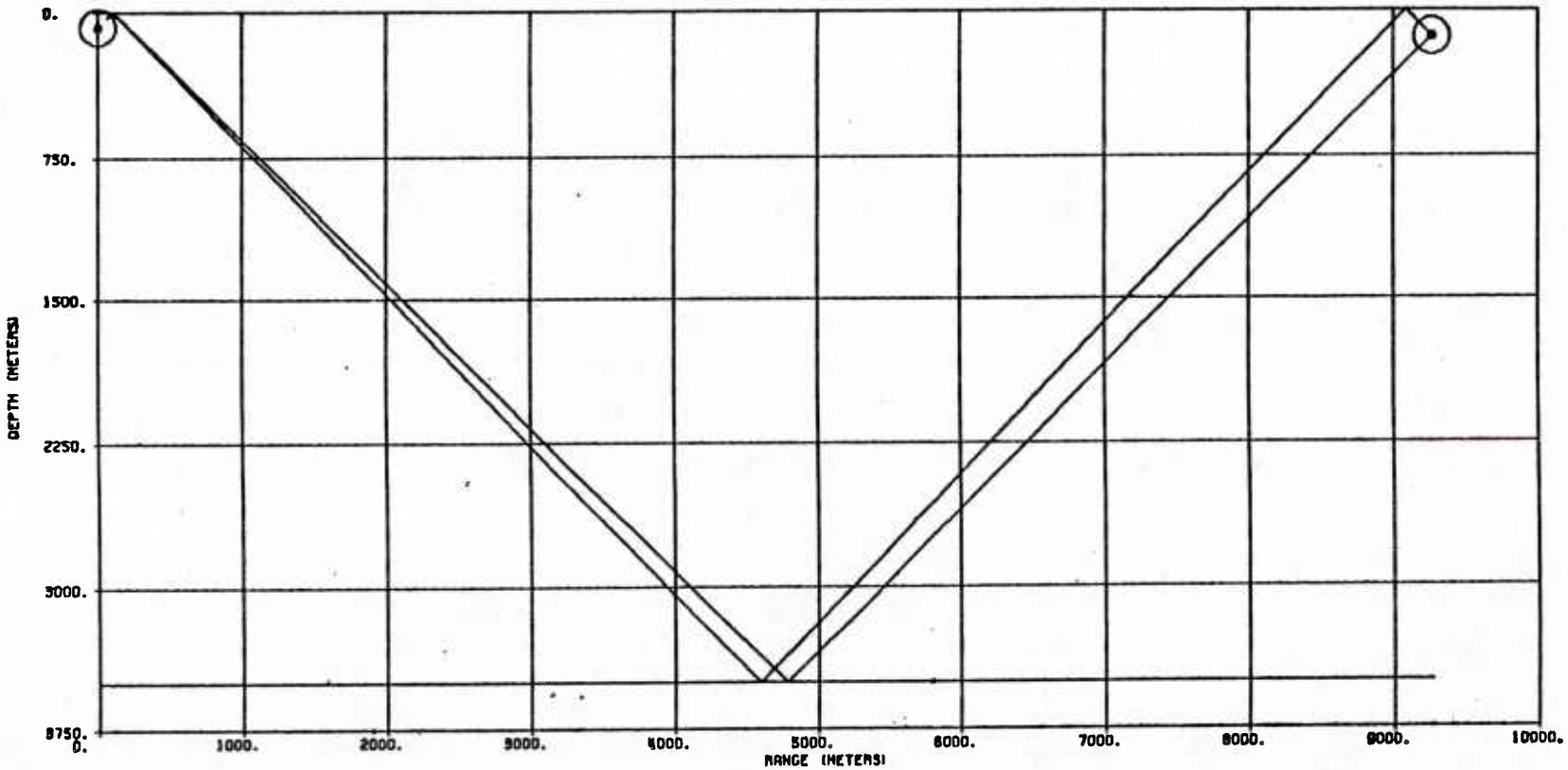


RUN FOR BT57C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-1.9	0.6	6.084	-3.2	0.0	88.84	1



RUN FOR BT57C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 9266.55 METERS

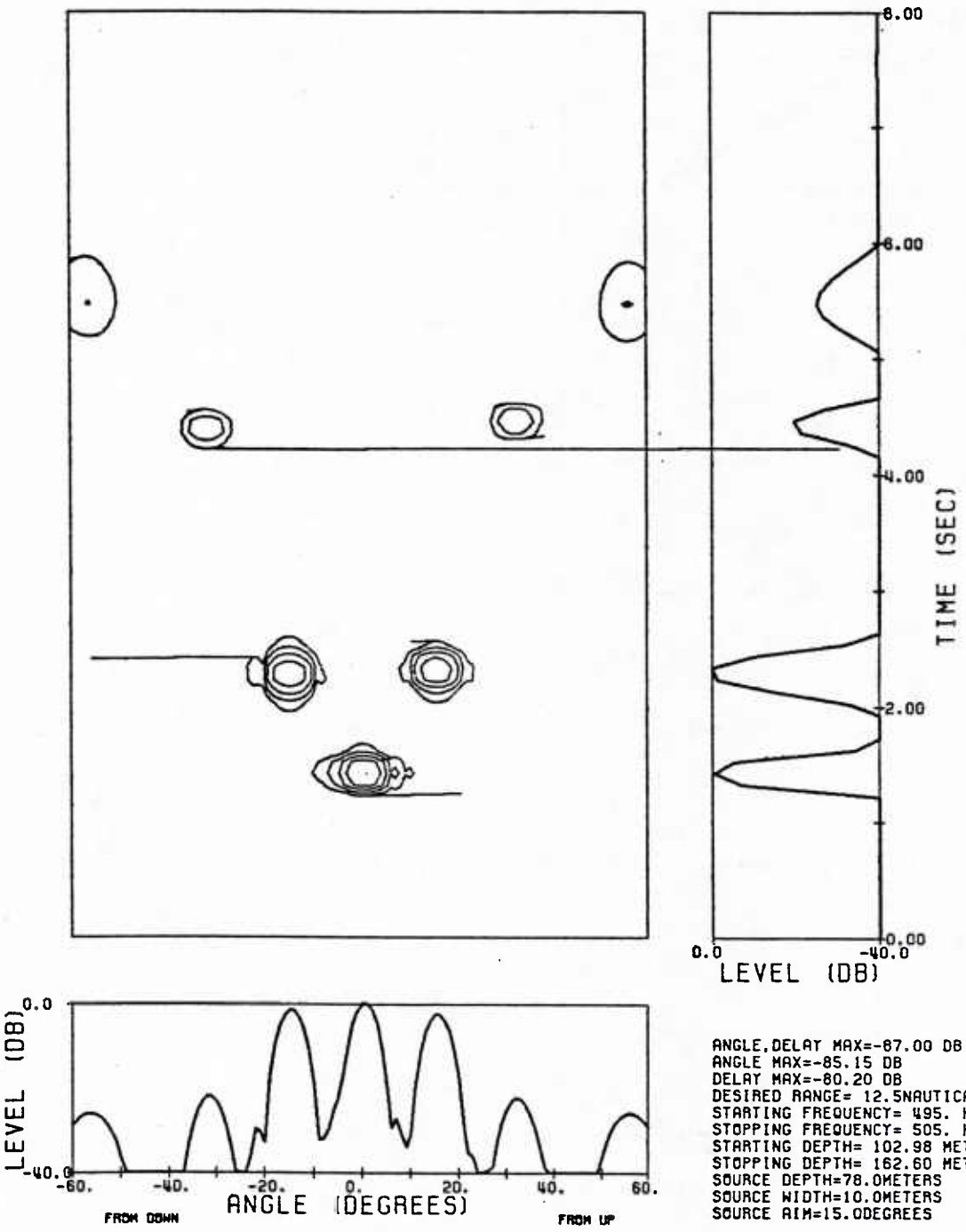
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-36.0	-36.0	7.684	-36.1	36.2	81.00	2
-97.1	97.1	7.790	-97.2	97.3	81.15	3

RANGE = 12.5 MILES

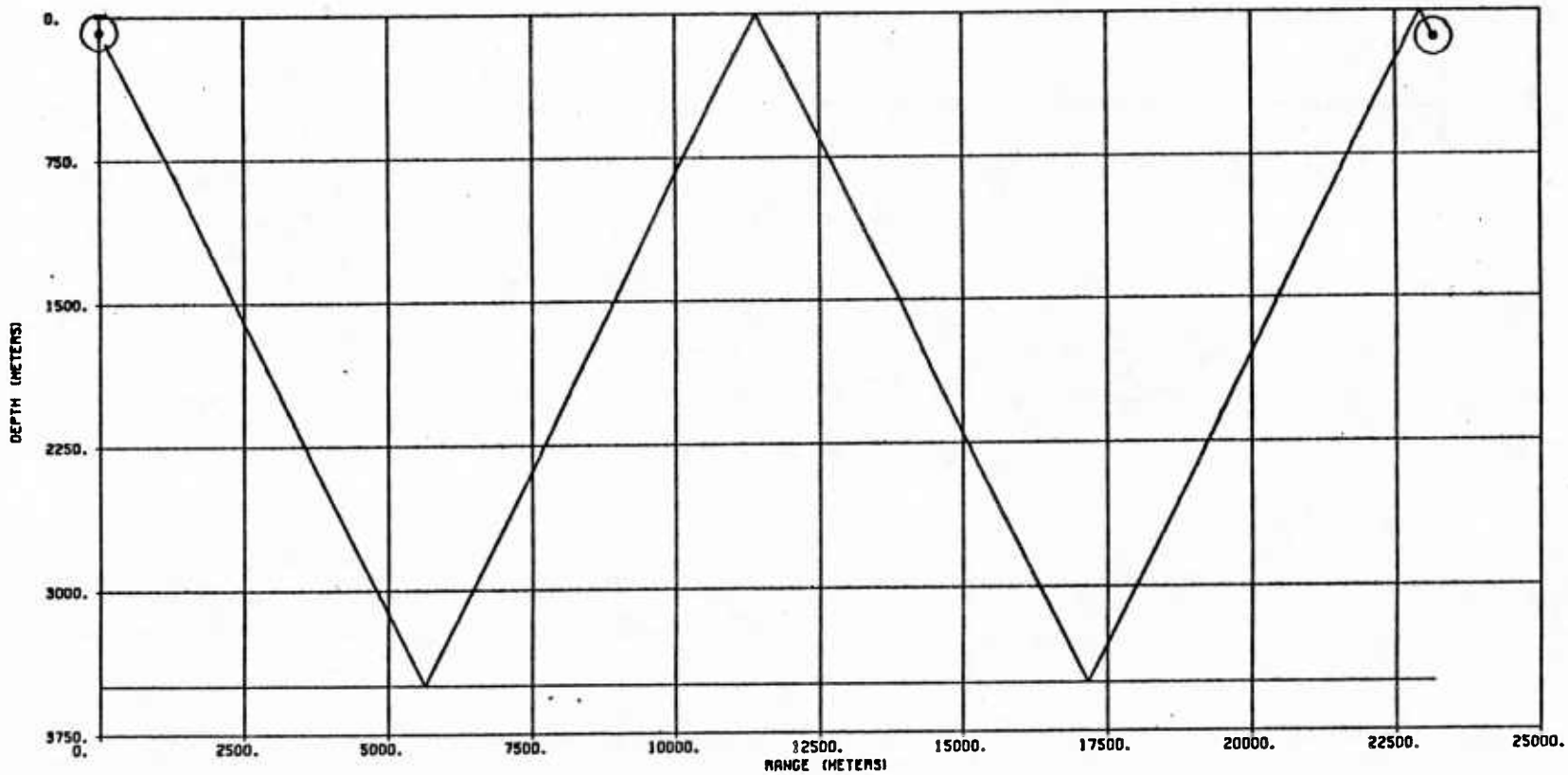
REVERSE BLANK

TM No. 811061

E11MAR35 RIDGE



ANGLE,DELAY MAX=-67.00 DB
ANGLE MAX=-85.15 DB
DELAY MAX=-80.20 DB
DESIRED RANGE= 12.5NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=15.0DEGREES

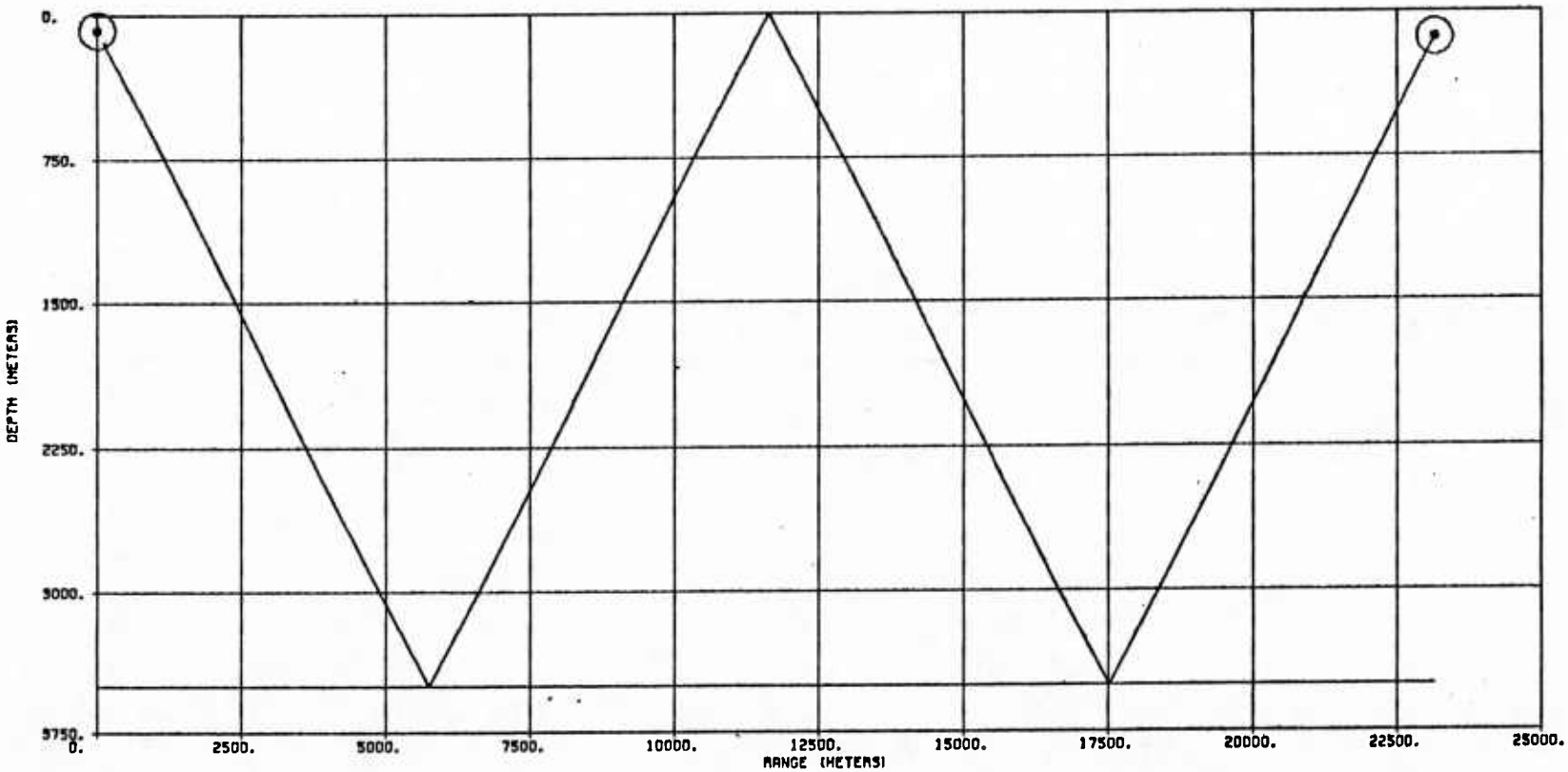


RUN FOR BT56C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
30.2	30.2	17.980	-30.3	30.4	88.30	4

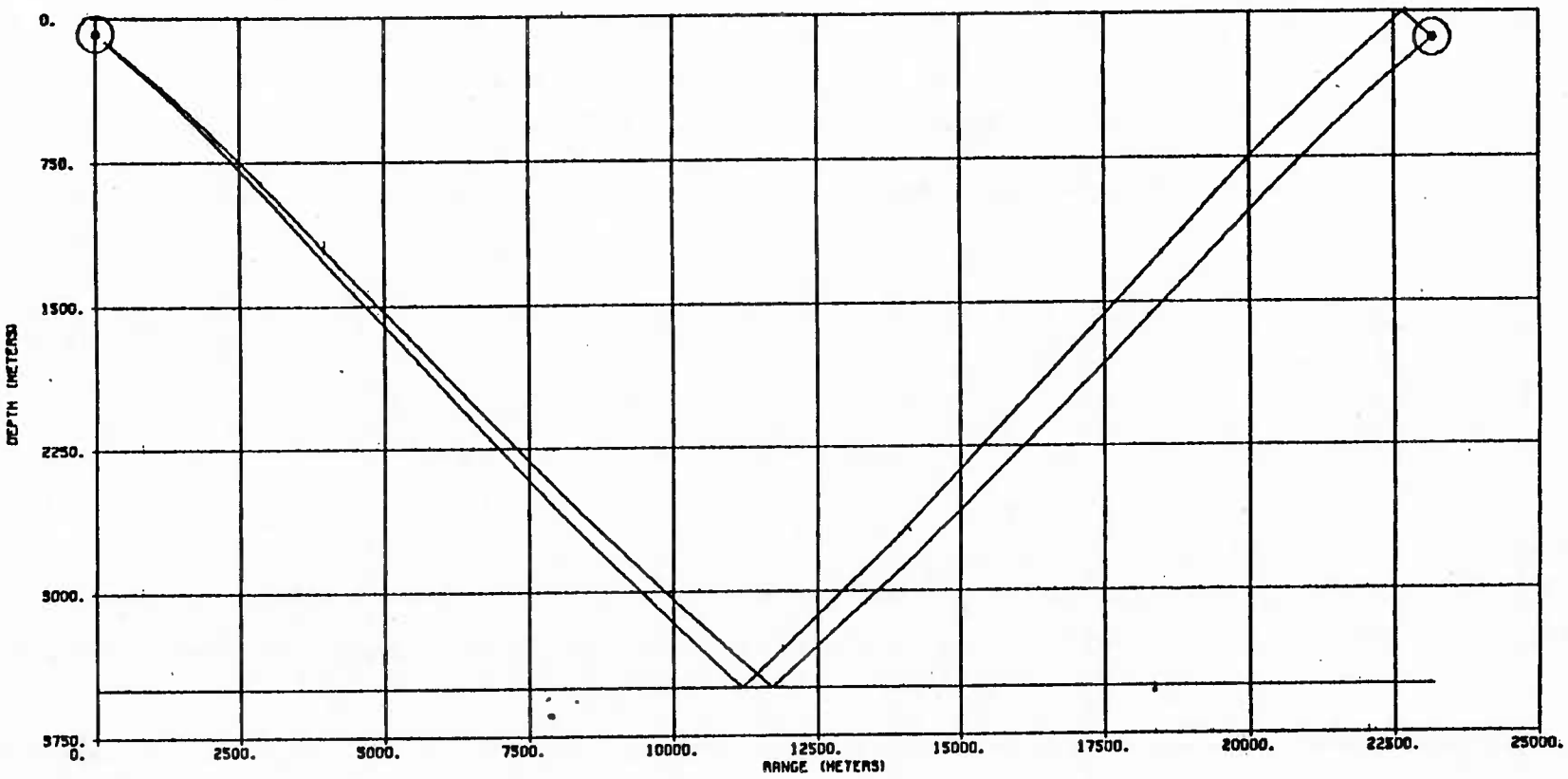


RUN FOR BT56C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
29.7	-29.6	17.891	-29.8	29.9	88.23	3

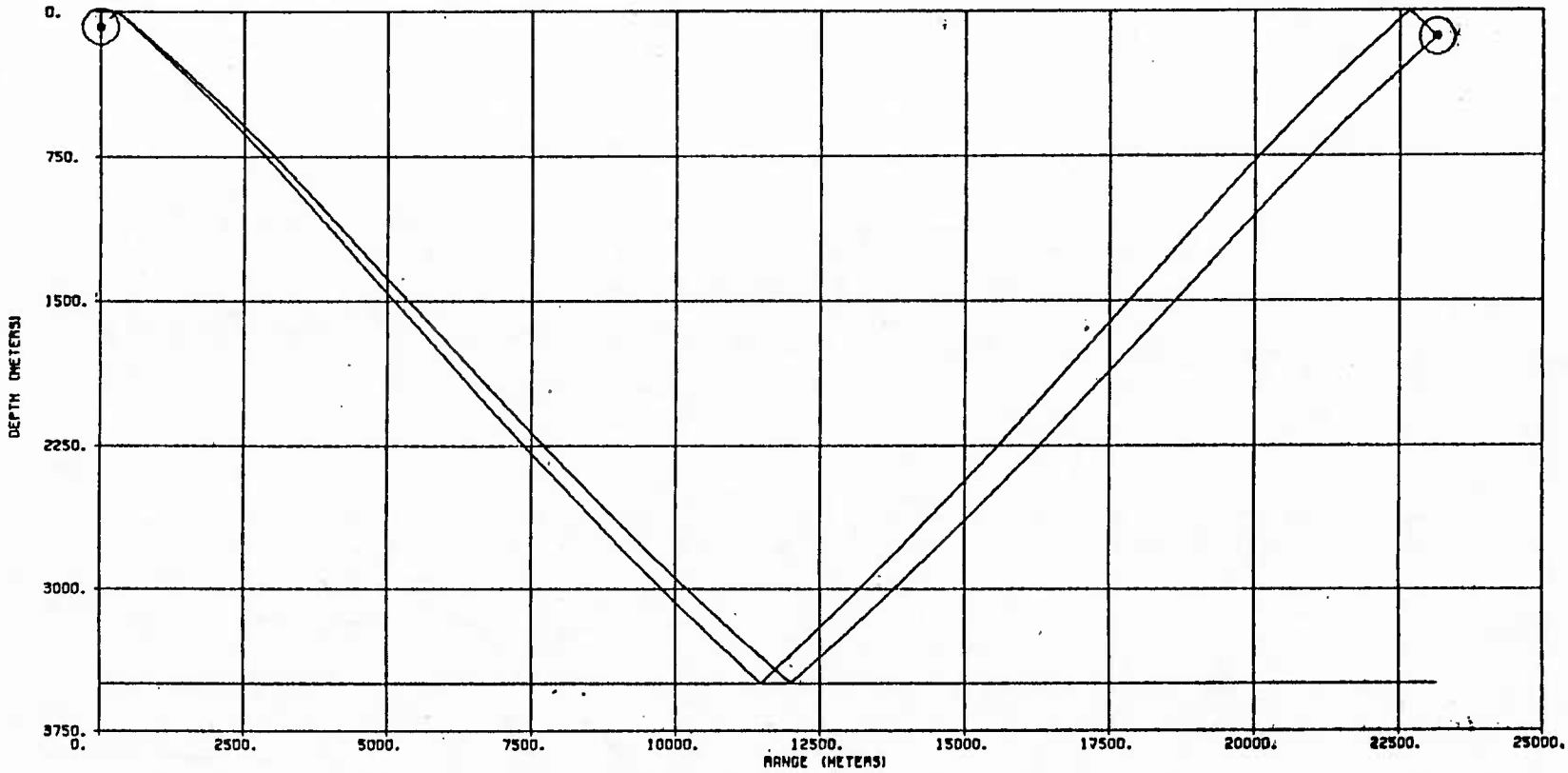


RUN FOR BT56C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
14.1	-14.0	16.021	0.0	14.8	86.53	1
14.9	14.8	16.066	-15.1	15.4	86.53	2

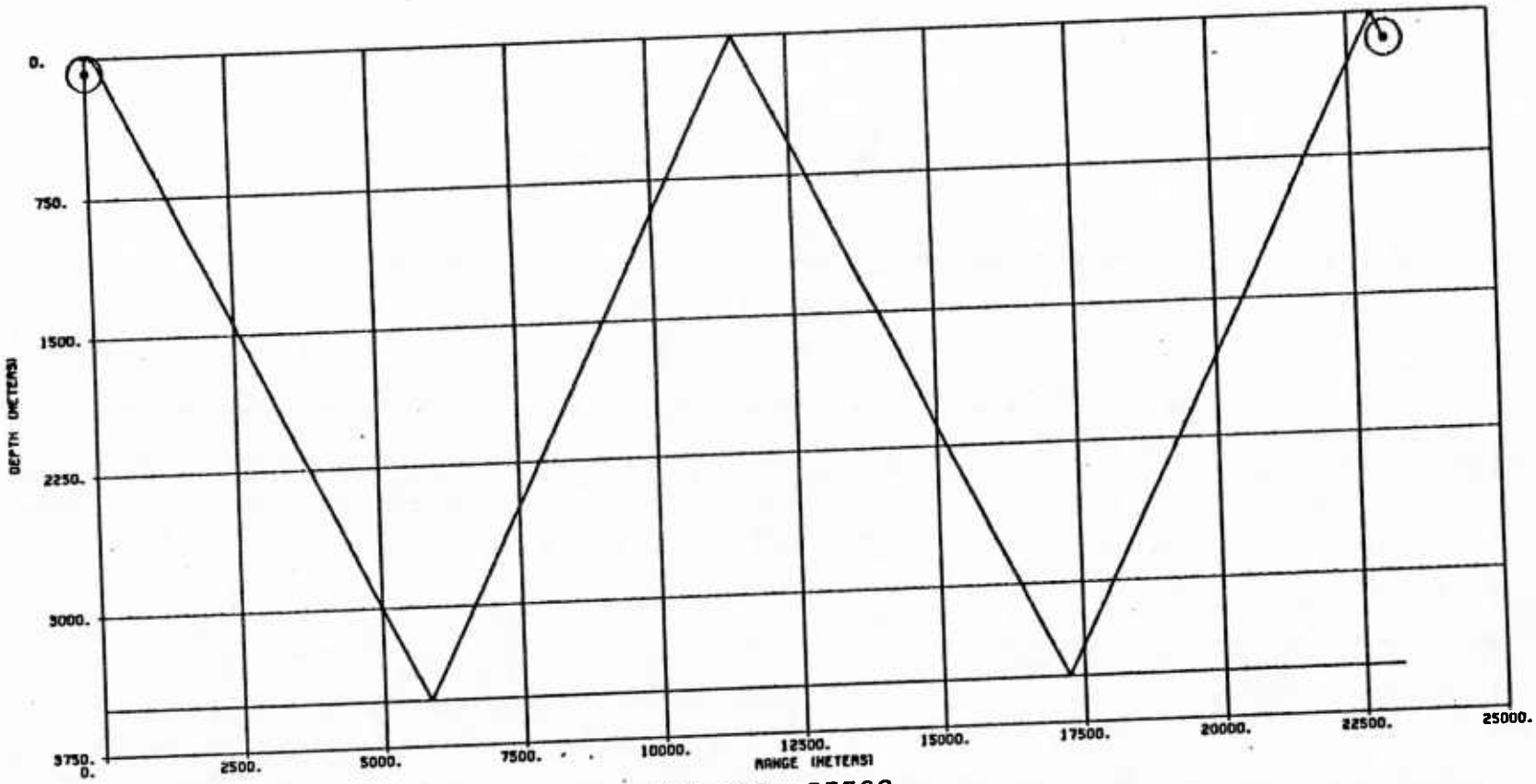


RUN FOR BT56C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-14.5	-14.4	16.048	-14.8	15.0	86.45	2
-15.9	15.2	16.093	-15.5	15.8	86.62	3



RUN FOR BT56C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 23166.37 METERS

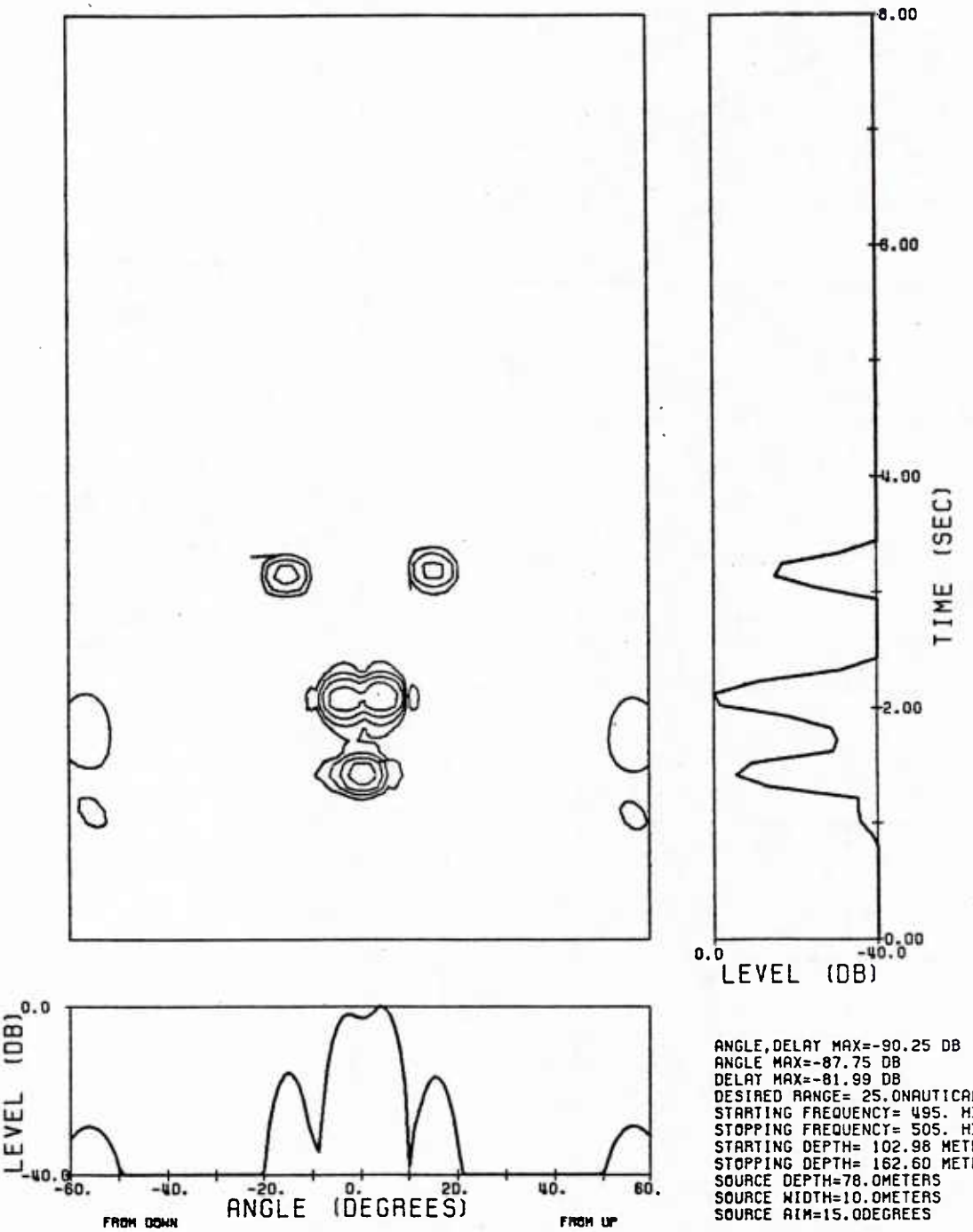
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-30.5	30.5	16.092	-30.6	30.7	88.33	5

RANGE = 25 MILES

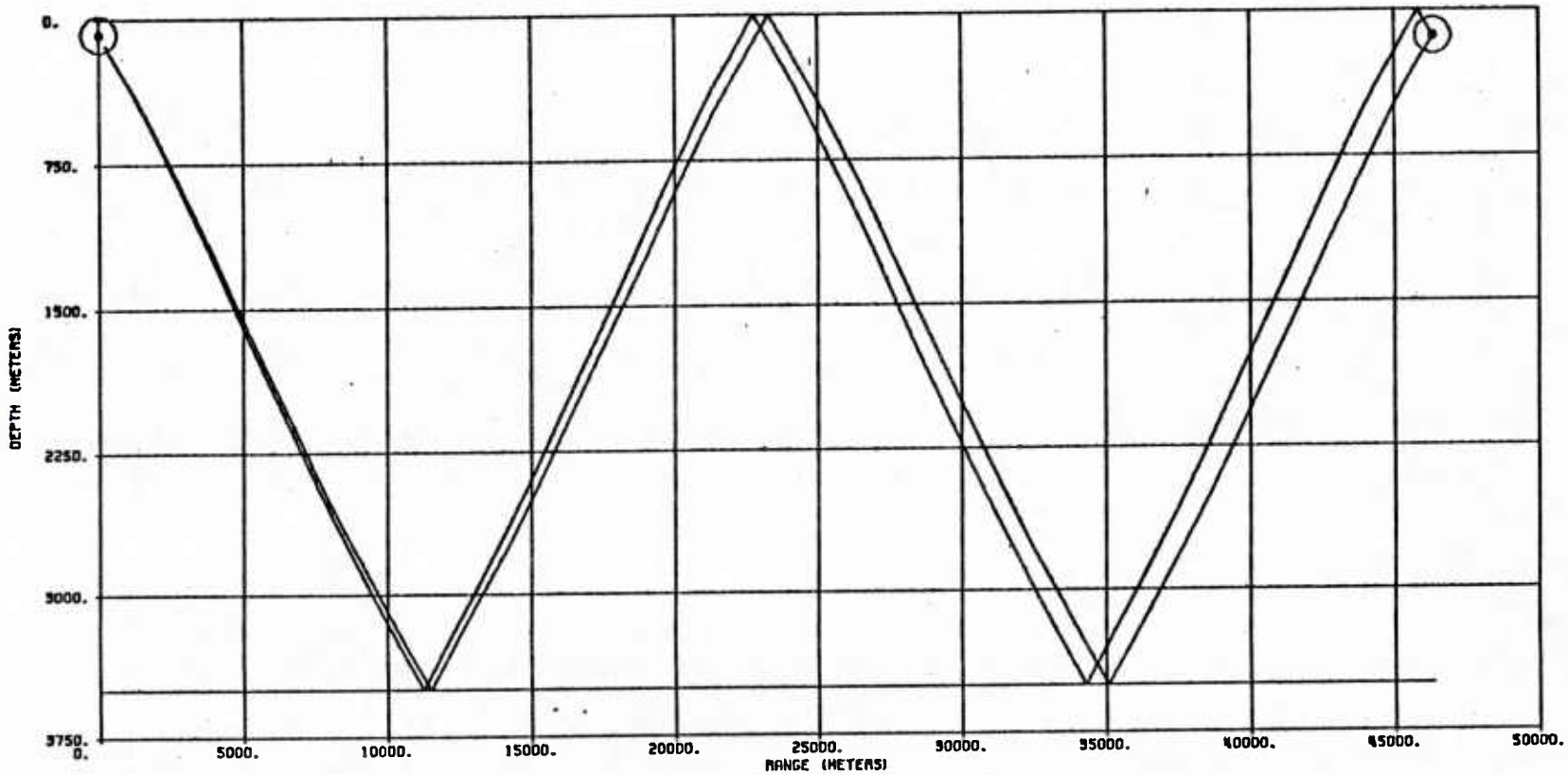
REVERSE BLANK

TM No. 811061

E11MAR35 RIDGE



ANGLE,DELAY MAX=-90.25 DB
ANGLE MAX=-87.75 DB
DELAY MAX=-81.99 DB
DESIRED RANGE= 25.0NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=15.0DEGREES

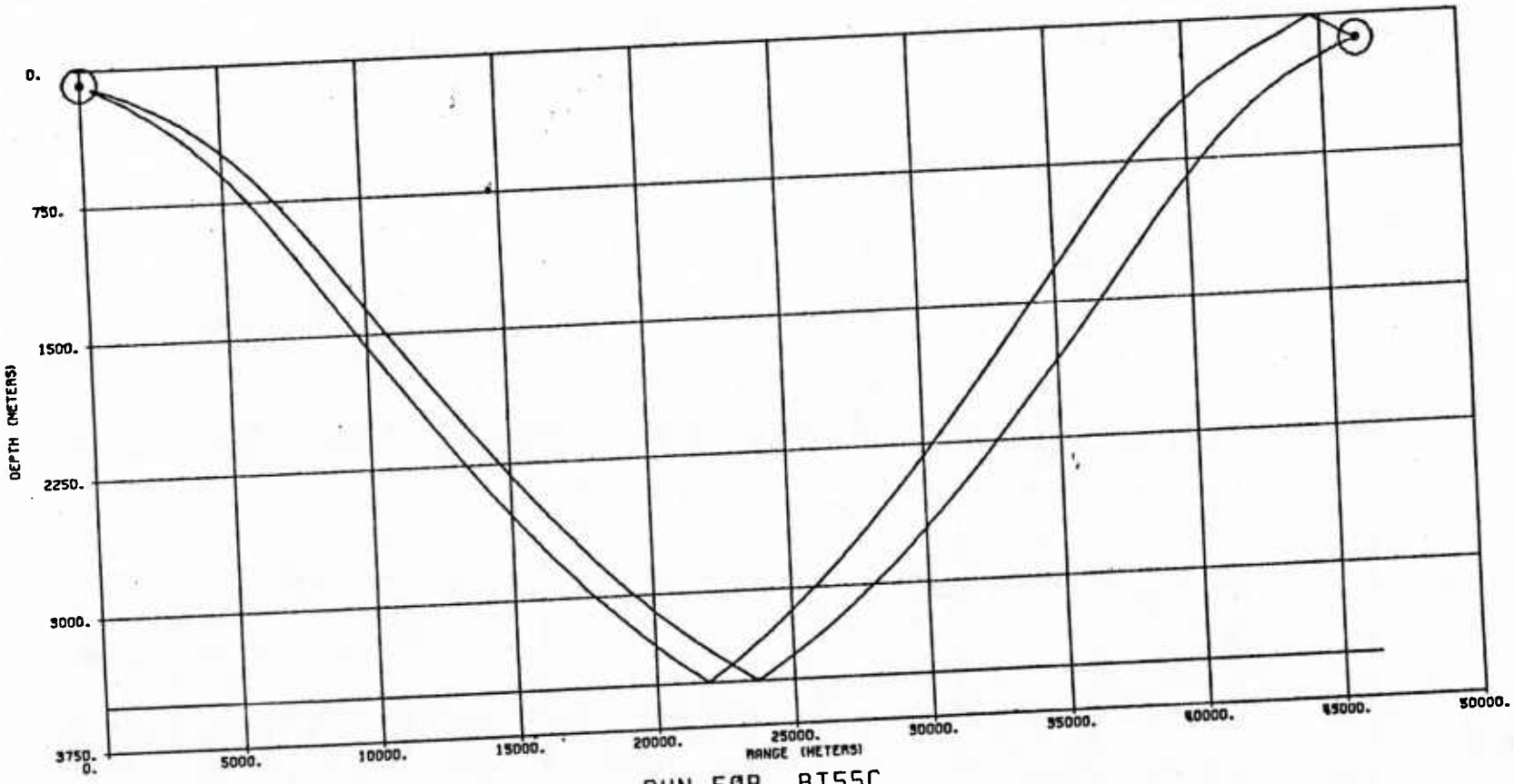


RUN FOR BT55C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
14.4	-14.3	32.076	-14.6	14.9	82.43	5
14.8	14.7	32.122	-15.0	15.3	82.53	4

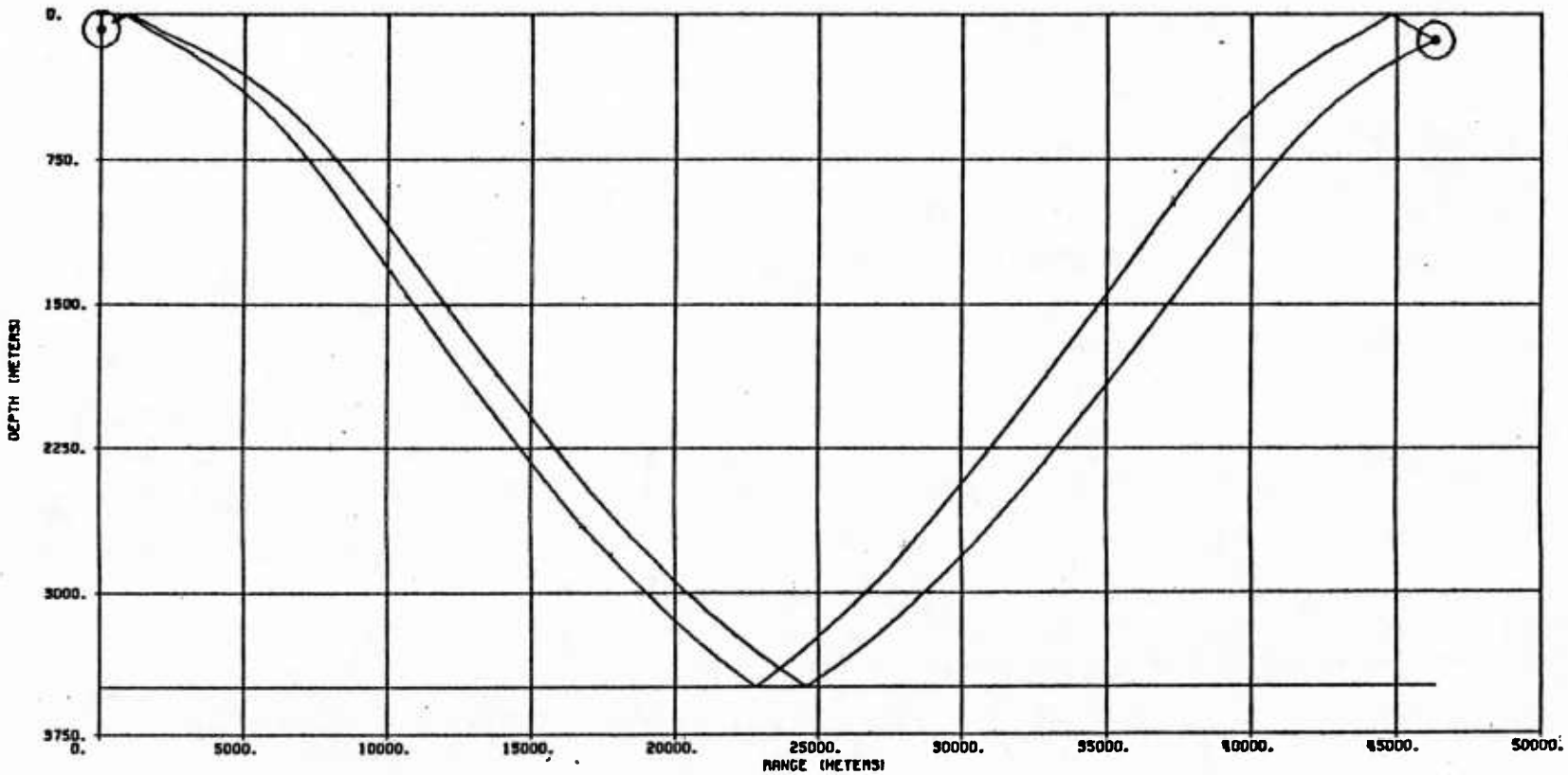


RUN FOR BT55C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
5.6	-5.2	31.059	0.0	5.5	87.30	1
4.6	4.2	31.072	-5.3	6.0	88.89	2

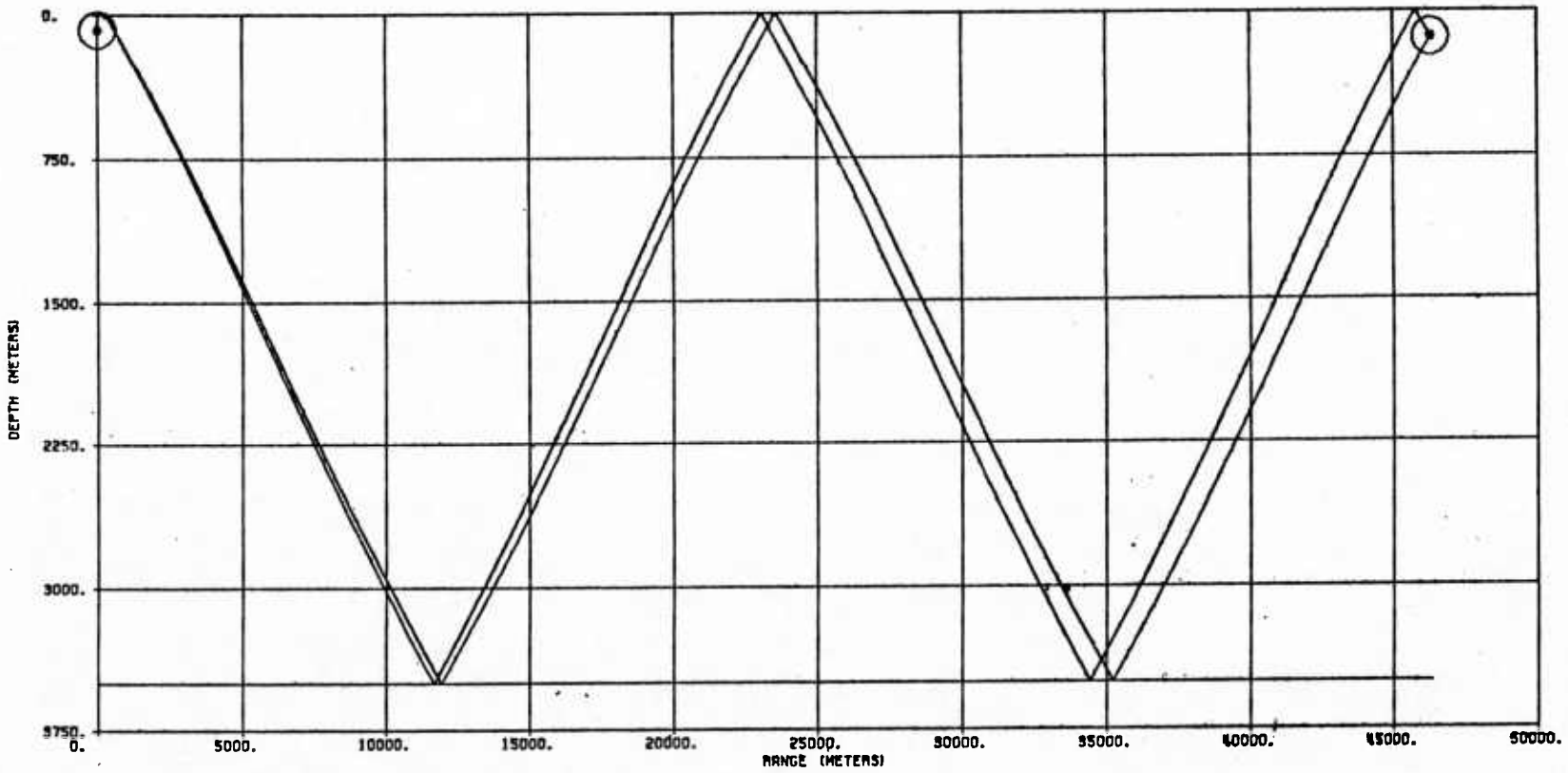


RUN FOR BT55C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46932.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-4.2	-3.8	31.066	-4.9	5.7	88.21	2
-5.1	4.7	31.081	-5.7	6.4	89.97	3



RUN FOR BT55C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 46332.74 METERS

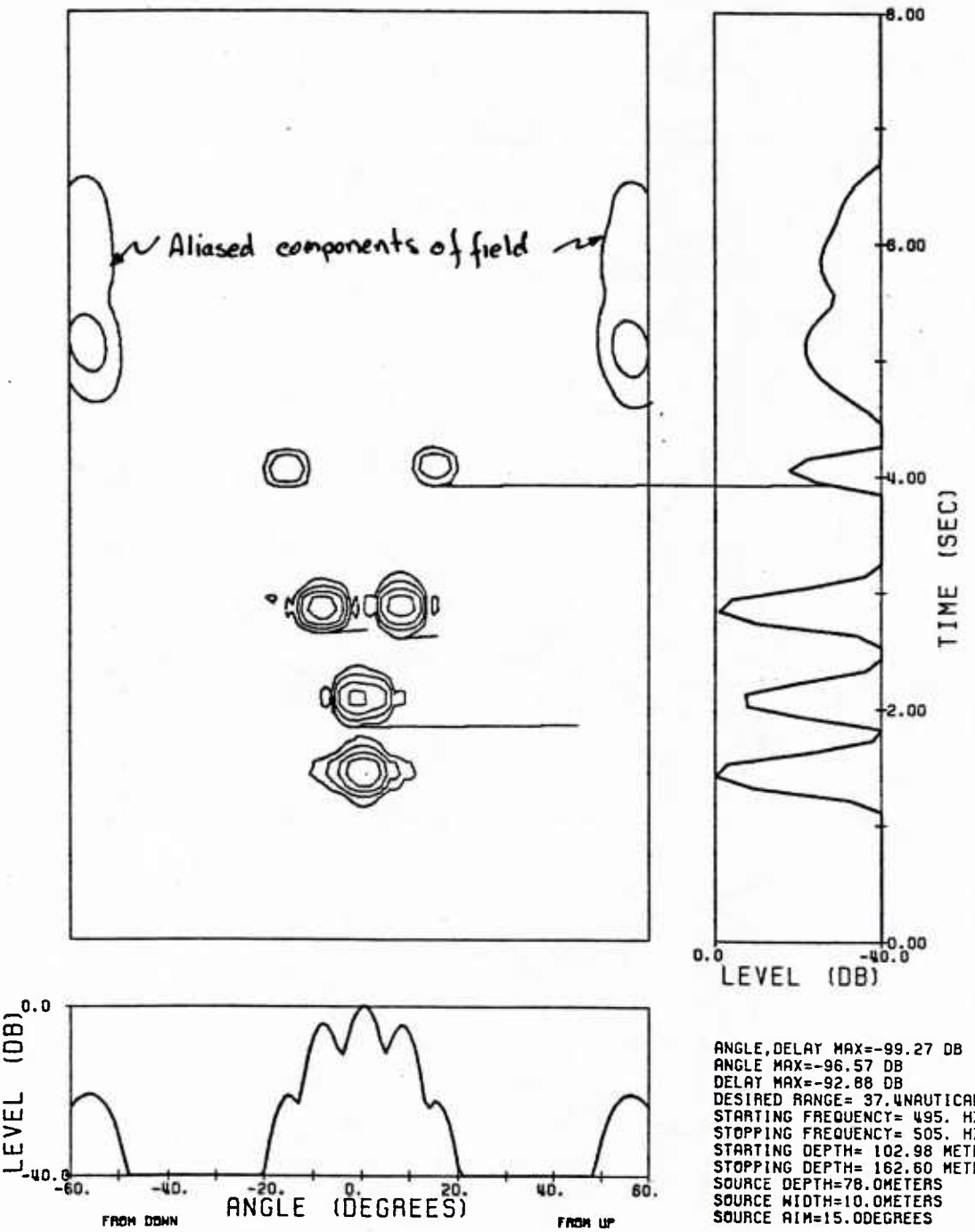
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-14.6	-14.5	32.102	-14.9	15.1	92.49	4
-15.0	14.9	32.148	-15.2	15.5	92.57	5

C25/C26 REVERSE BLANK

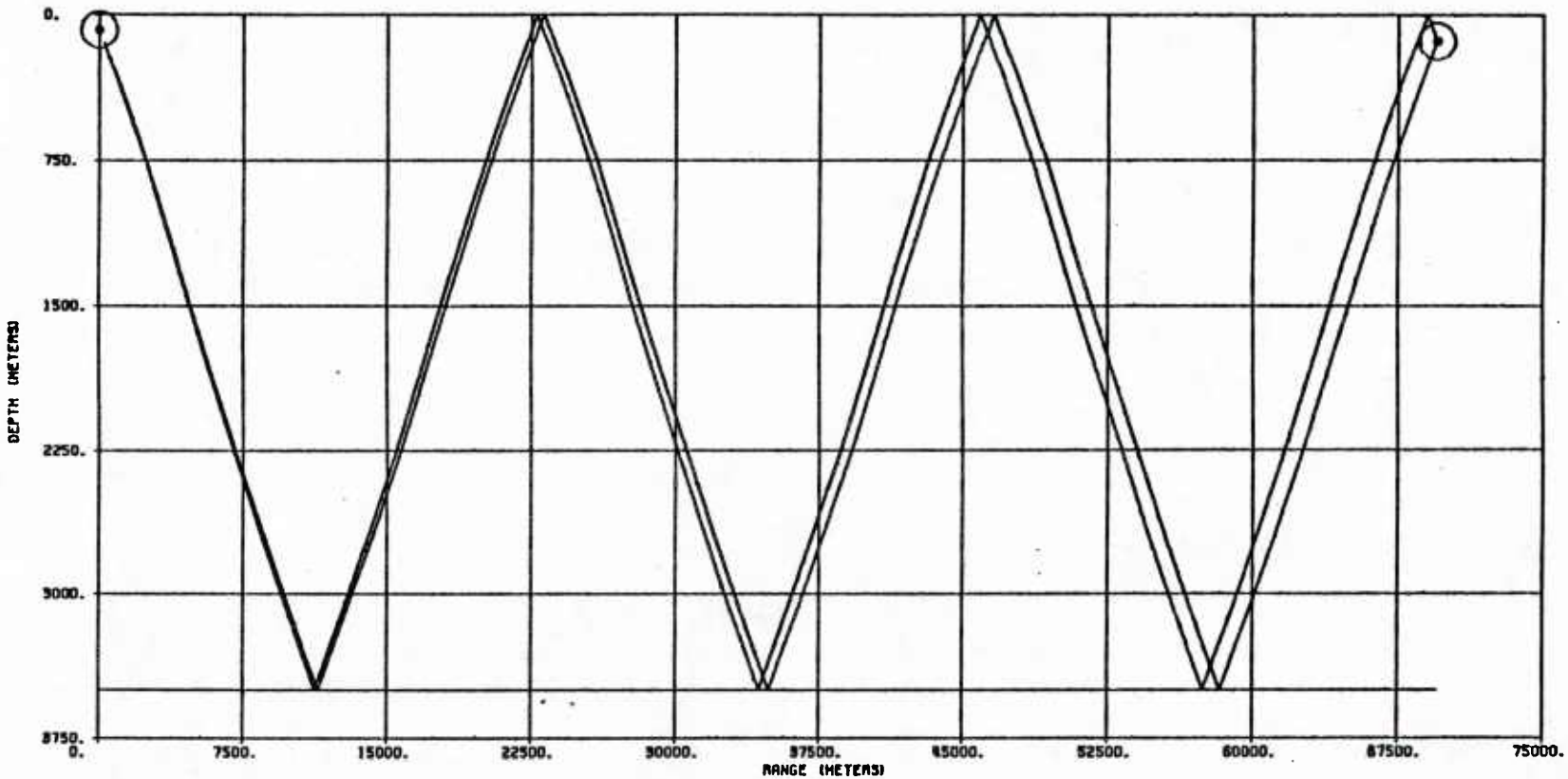
RANGE = 37.5 MILES

REVERSE BLANK

E11MAR35 RIDGE



ANGLE,DELAY MAX=-99.27 DB
ANGLE MAX=-96.57 DB
DELAY MAX=-92.88 DB
DESIRED RANGE= 37.4NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=15.0DEGREES

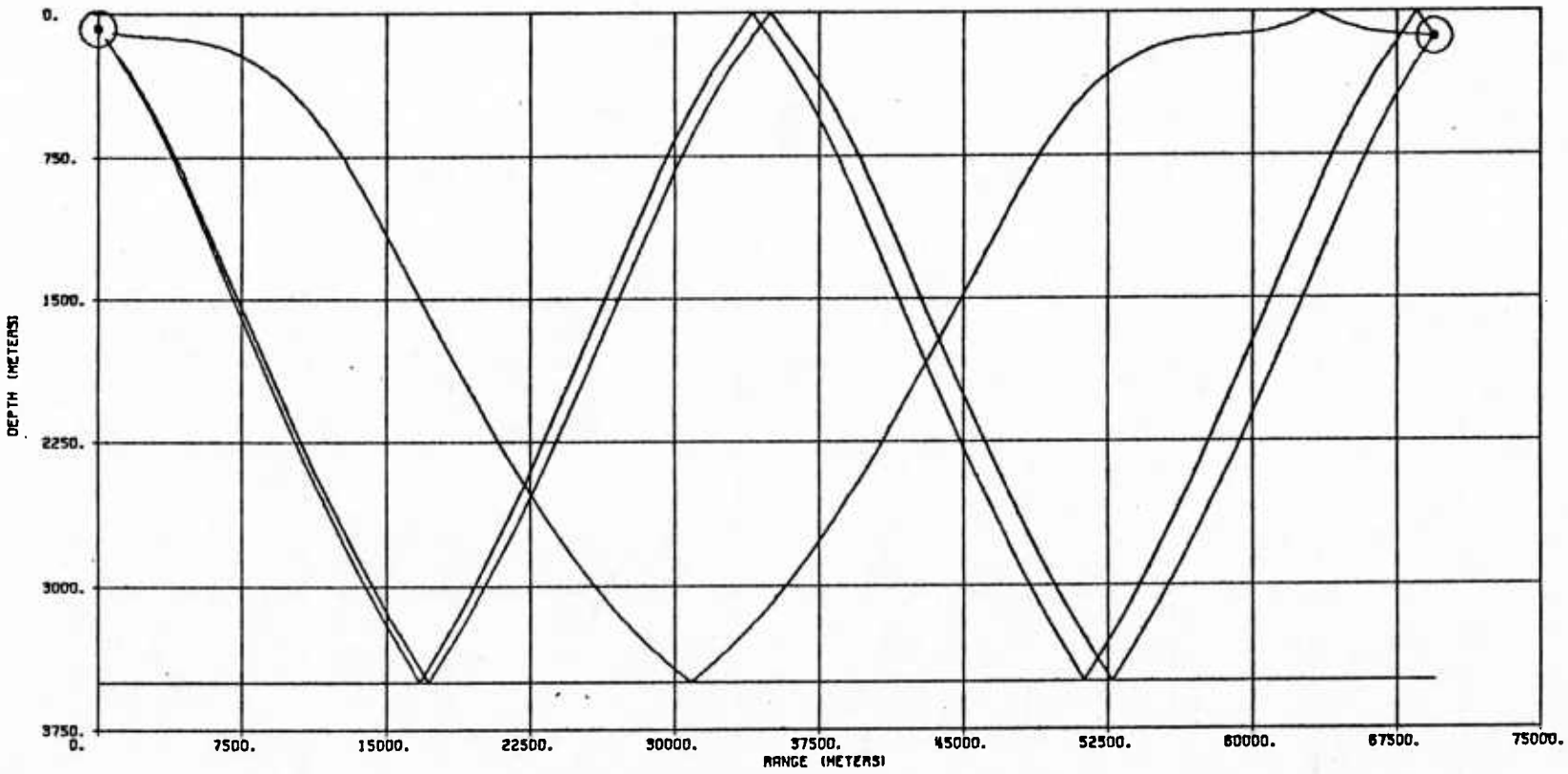


RUN FOR BT54C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 69489.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
14.5	-14.4	48.152	-14.7	15.0	85.98	5
14.8	14.7	48.177	-15.0	15.3	96.04	6

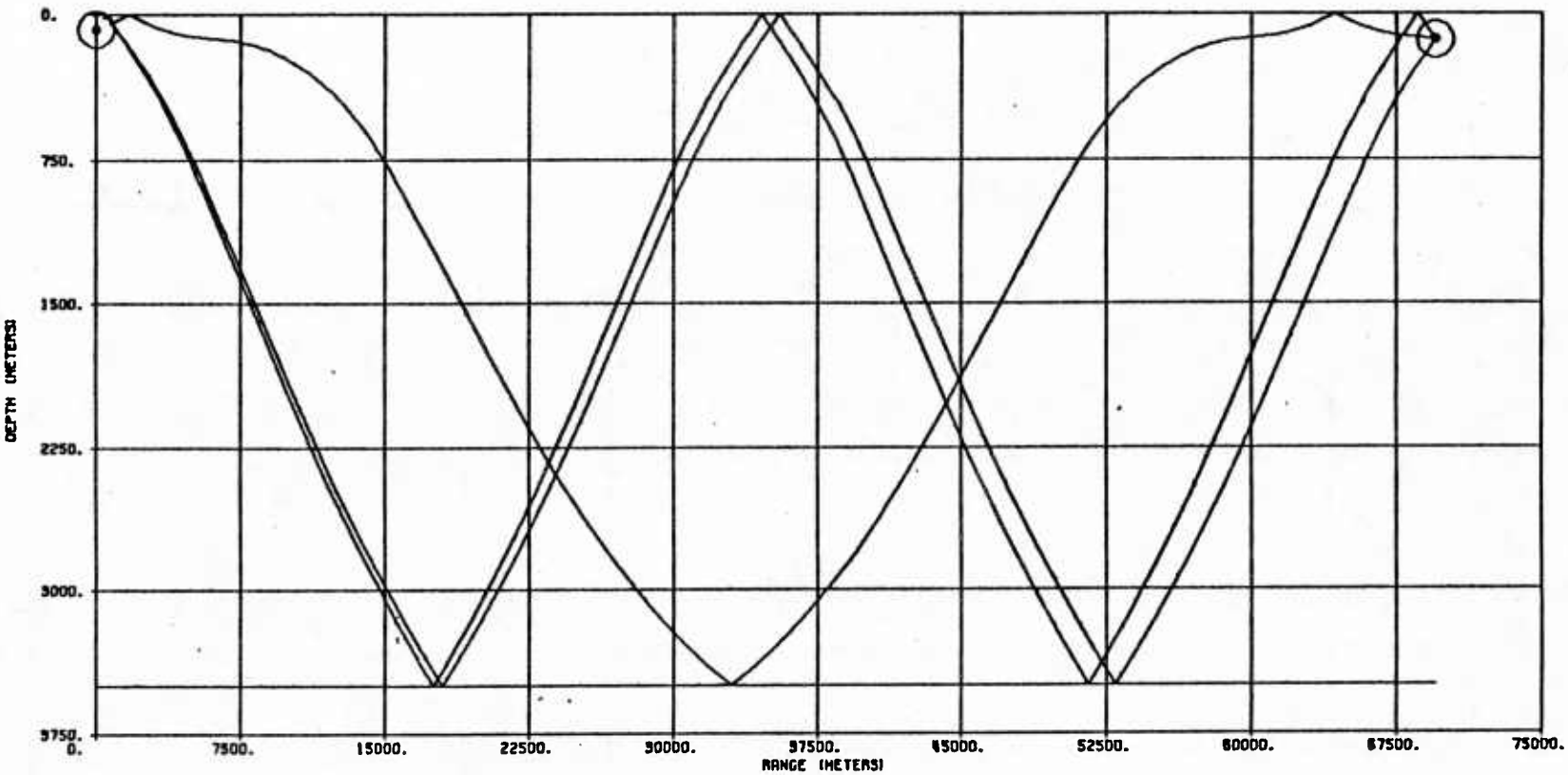


RUN FOR BT54C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 69499.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.0	0.7	46.258	-3.2	4.4	97.23	2
7.9	-7.7	47.004	-8.3	8.8	94.16	3
8.3	8.1	47.029	-8.7	9.2	94.42	4

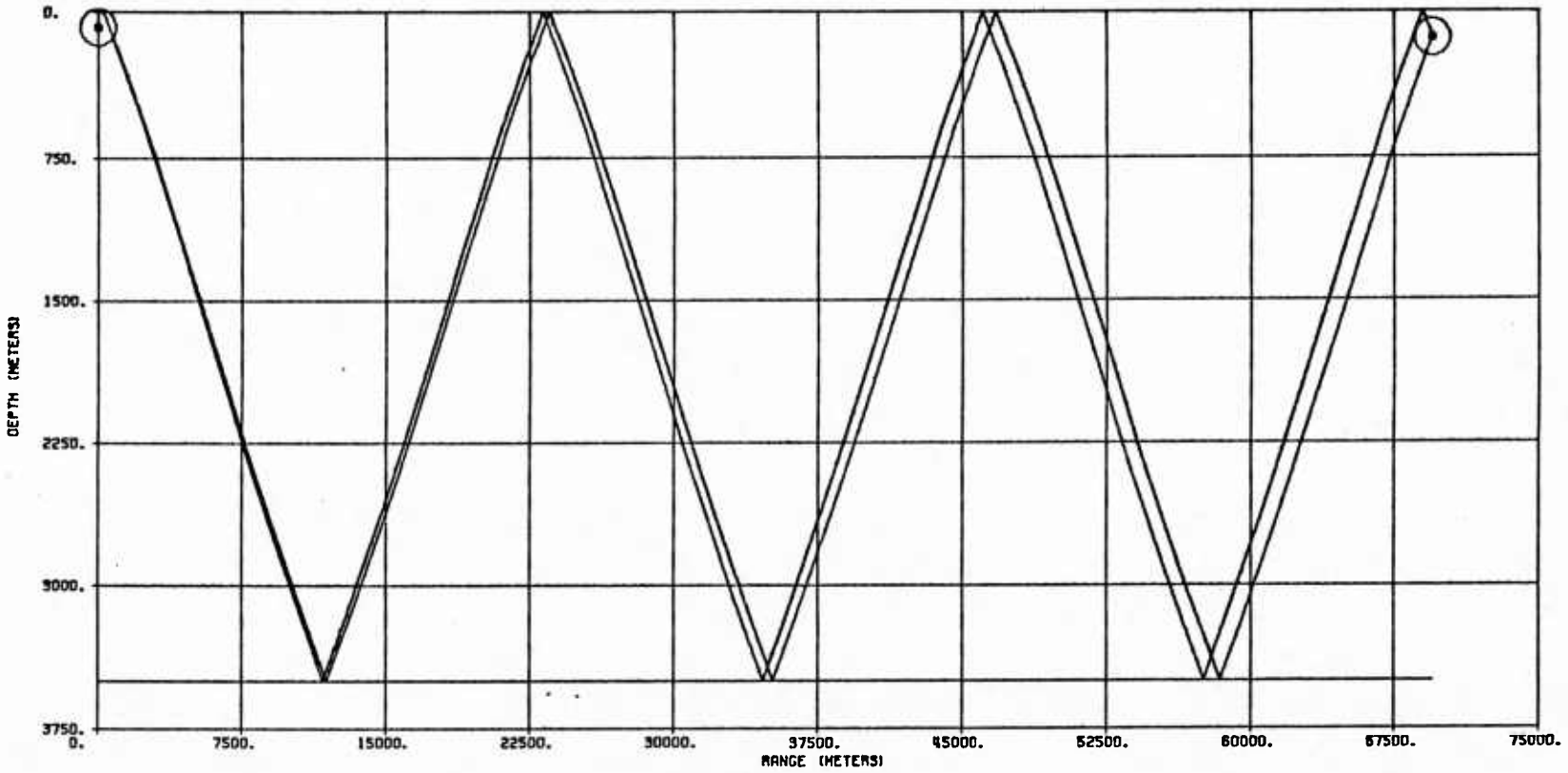


RUN FOR BT54C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 69499.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.0	0.8	46.269	-3.9	4.4	93.84	3
-8.1	-7.9	47.018	-8.5	9.0	94.31	4
-8.5	8.3	47.044	-8.9	9.4	94.53	5



RUN FOR BT54C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 69499.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-14.7	-14.5	48.158	-14.9	15.2	96.02	6
-14.9	14.8	48.204	-15.1	15.4	96.08	7

C33/C34 REVERSE BLANK

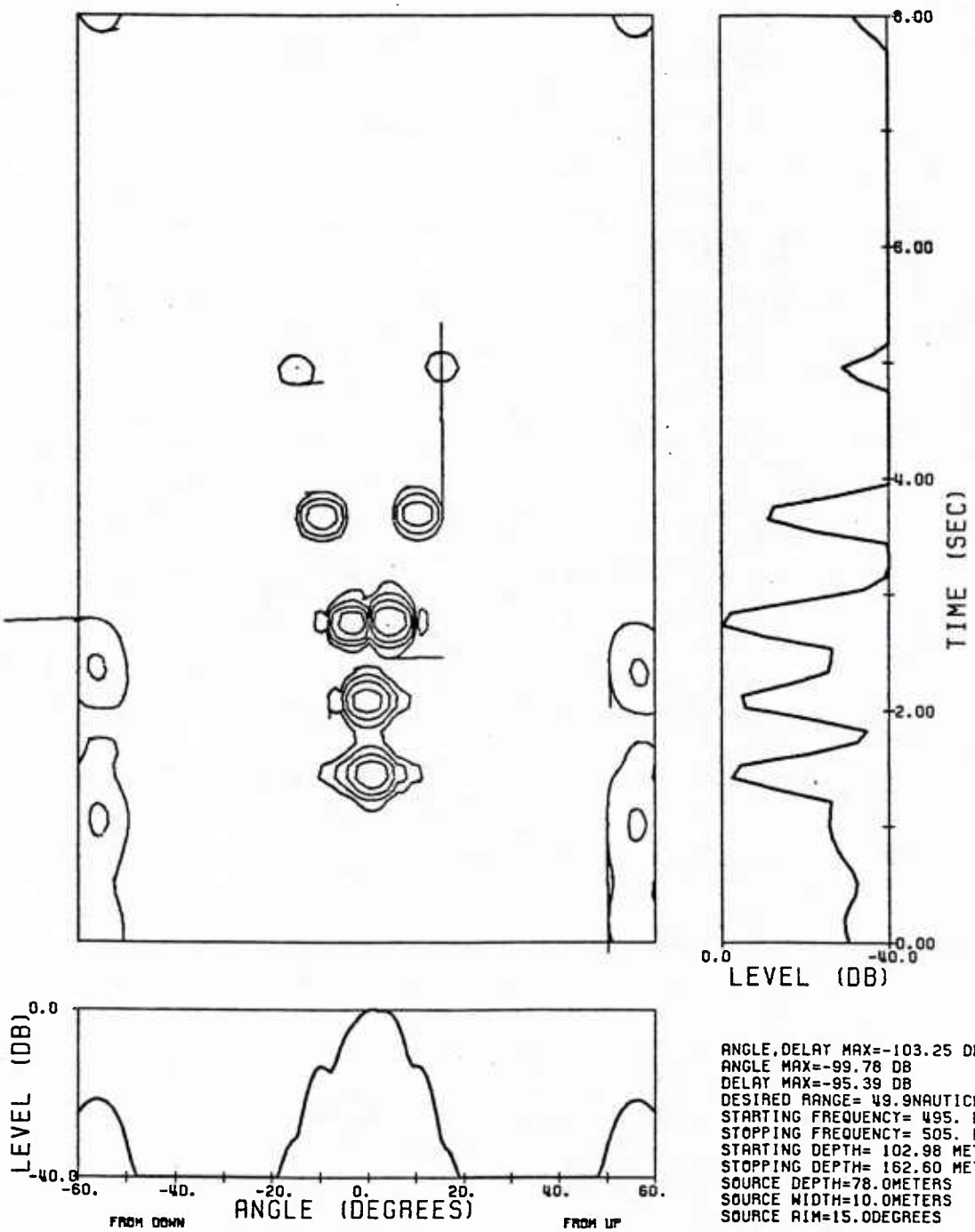
TM No. 811061

RANGE = 50 MILES

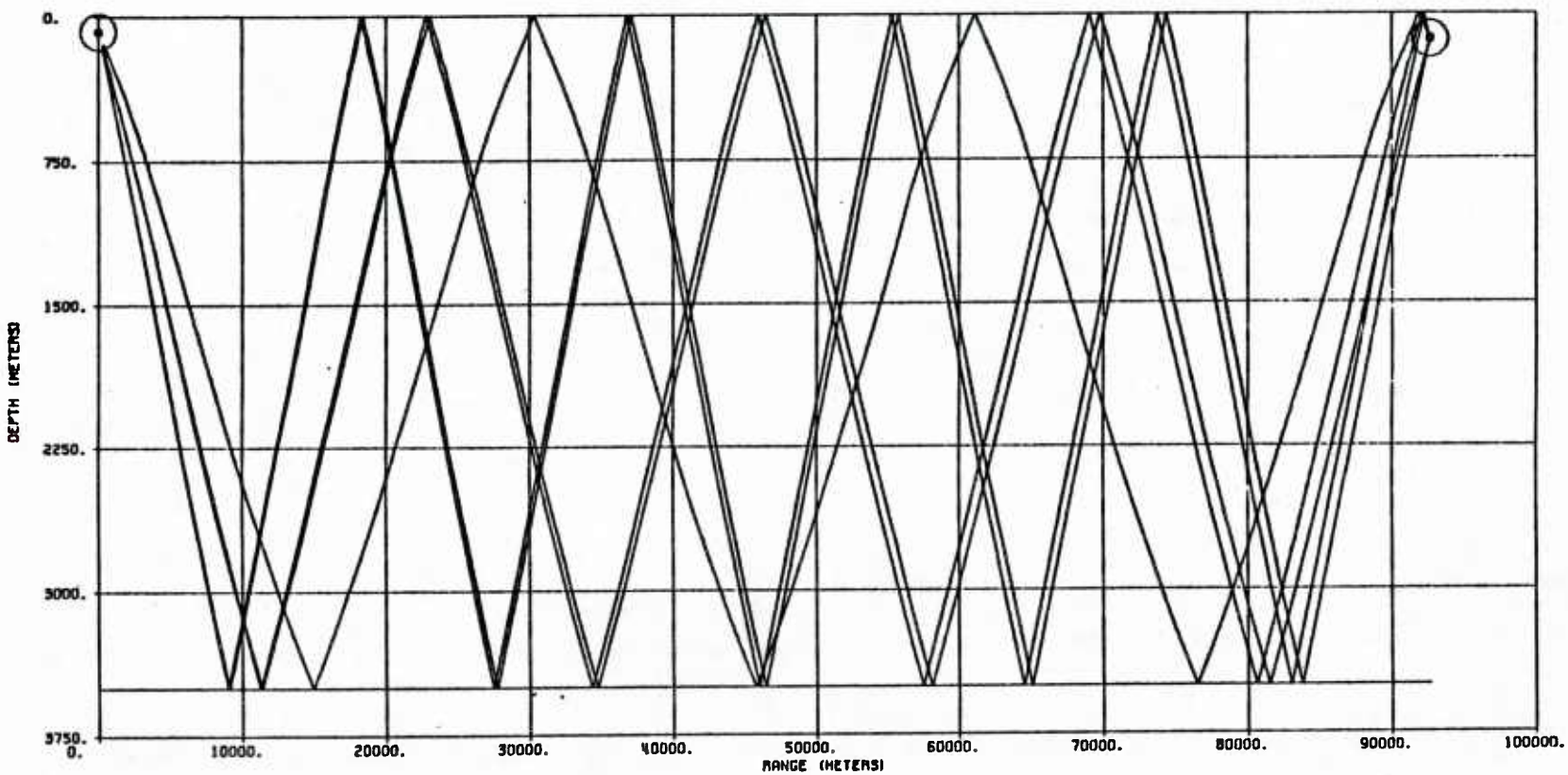
REVERSE BLANK

TM No. 811061

E11MAR35 RIDGE



ANGLE,DELAY MAX=-103.25 DB
ANGLE MAX=-99.78 DB
DELAY MAX=-95.39 DB
DESIRED RANGE= 49.9NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE RIM=15.0DEGREES

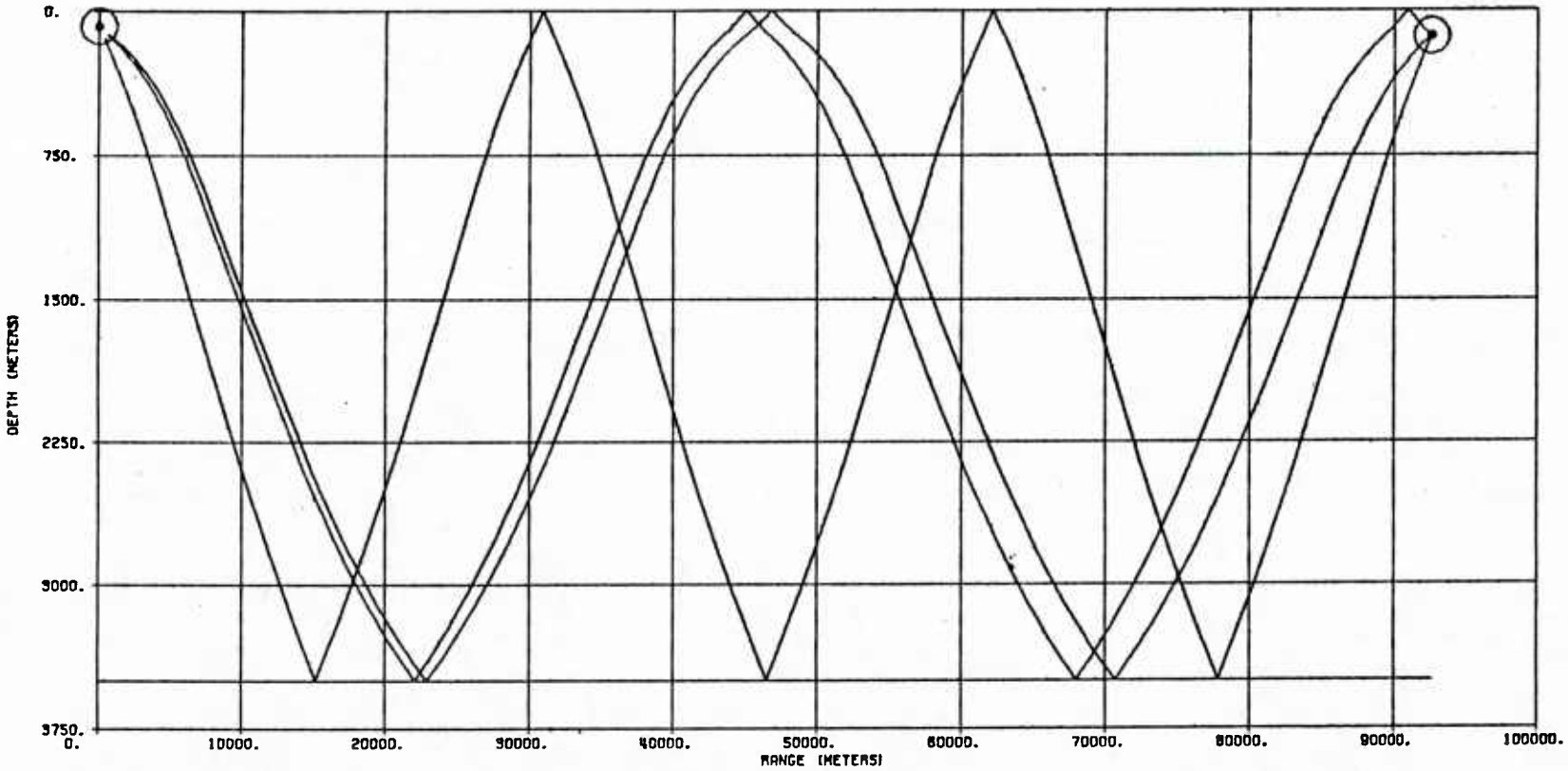


RUN FOR BT53C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
10.0	9.8	63.035	-10.3	10.7	97.49	6
14.6	-14.4	64.188	-14.8	15.1	98.49	7
14.8	14.6	64.233	-15.0	15.3	98.54	8
18.9	-18.8	65.676	-19.1	19.3	99.11	9
19.1	19.0	65.734	-19.2	19.4	99.14	10

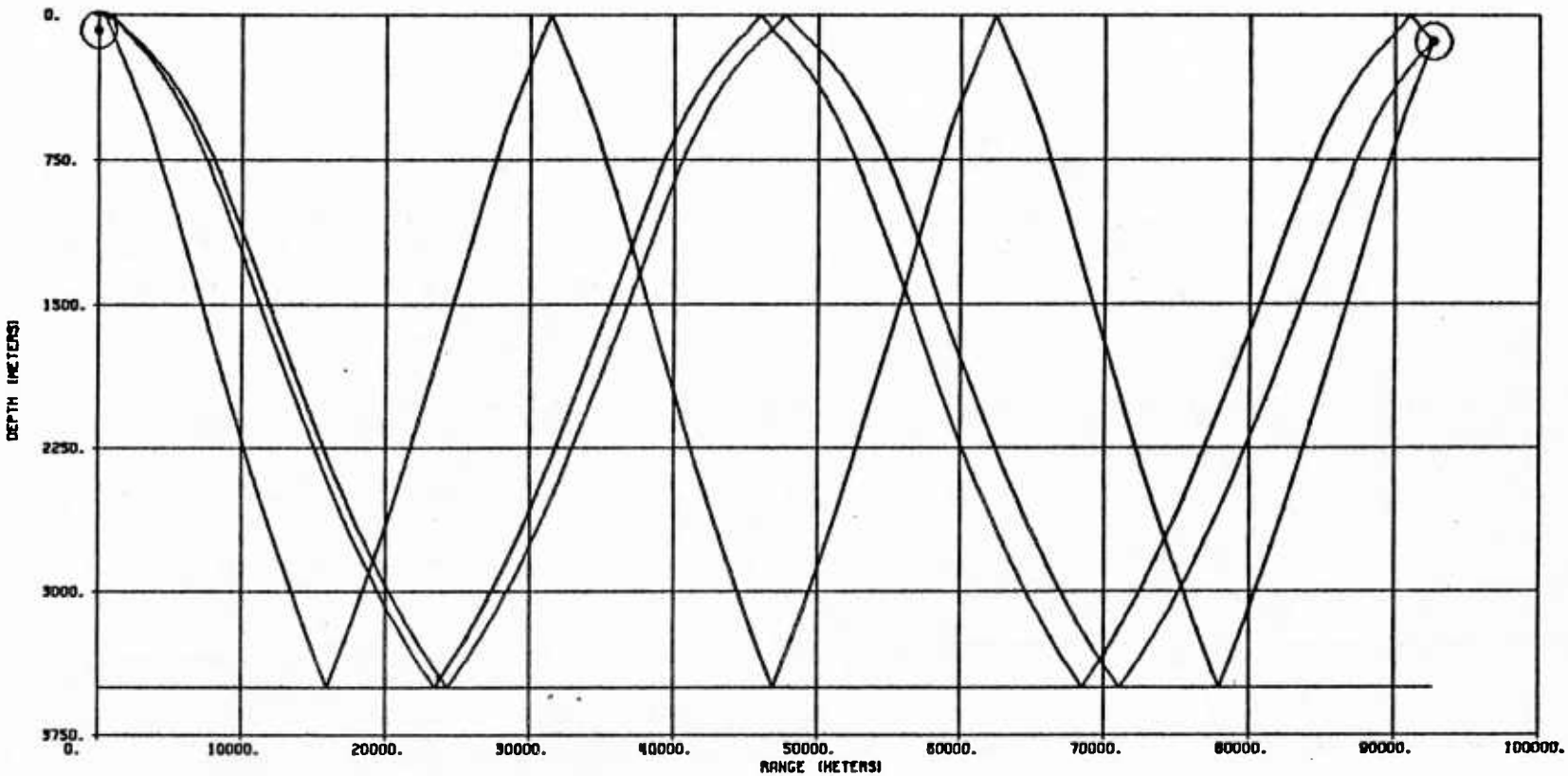


RUN FOR BT53C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
4.1	-3.6	62.127	-4.8	5.6	94.06	3
4.5	4.1	62.141	-5.2	6.0	94.77	4
9.8	-8.6	63.004	-10.1	10.5	97.37	5

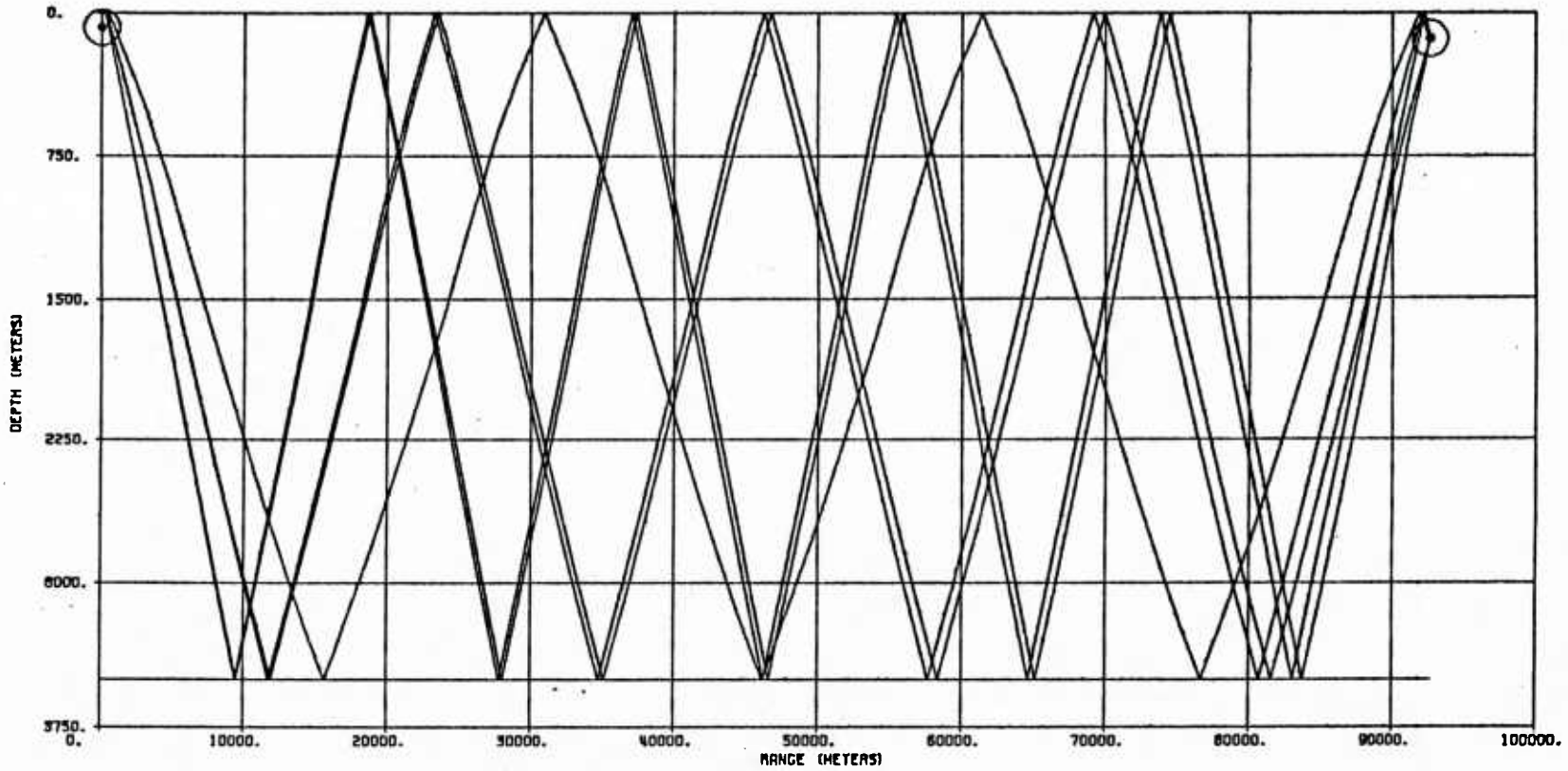


RUN FOR BT53C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 138.00 METERS
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-4.3	-3.9	62.138	-5.0	5.8	94.42	4
-4.8	4.4	62.150	-5.4	6.1	95.02	5
-9.9	-9.7	63.022	-10.2	10.6	97.44	6



RUN FOR BT53C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 92665.49 METERS

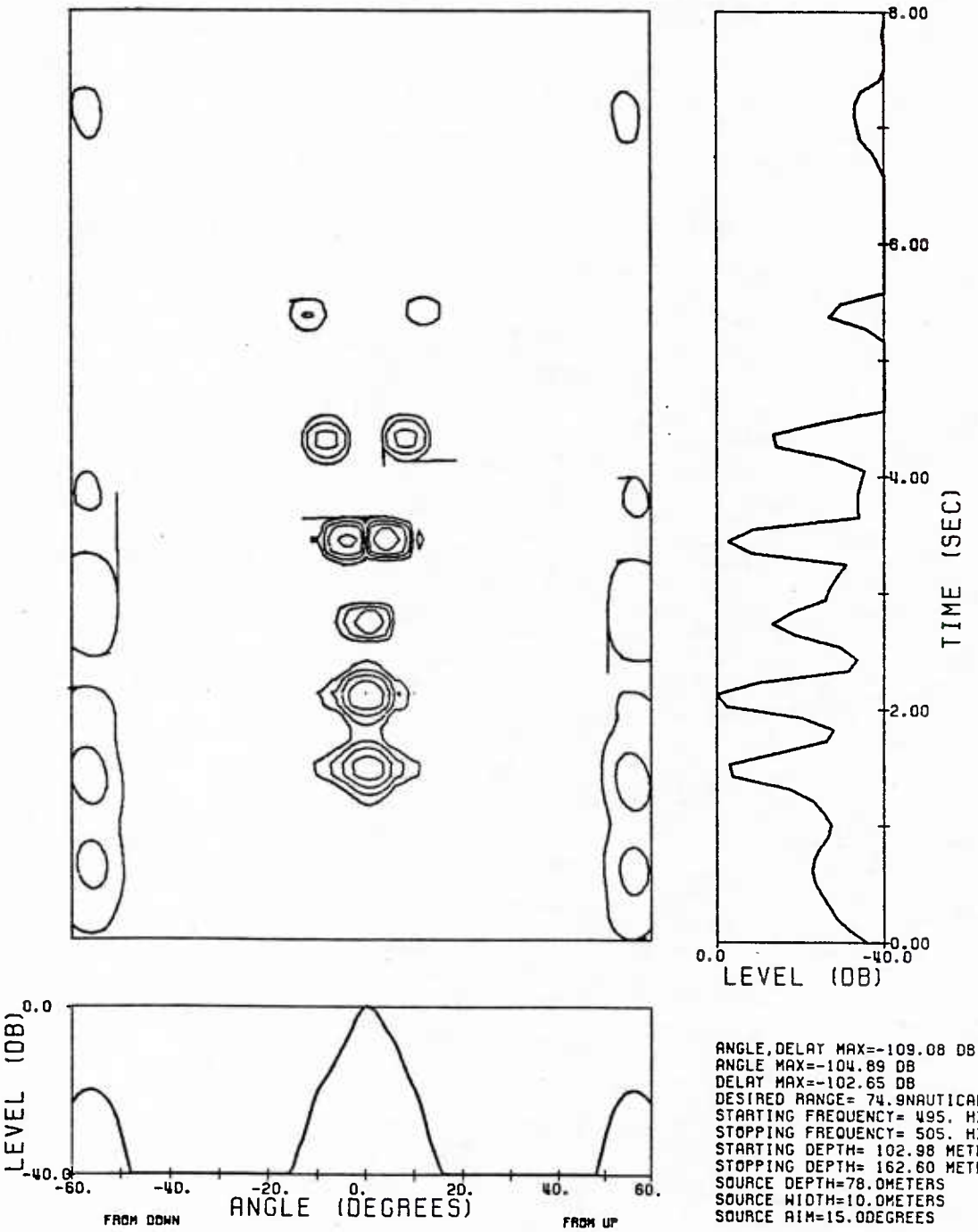
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-10.2	10.0	63.059	-10.5	10.9	97.56	7
-14.7	-14.6	64.214	-14.9	15.2	98.52	8
-14.8	14.8	64.260	-15.1	15.4	98.56	9
-19.0	-18.9	65.710	-19.2	19.4	99.12	10
-19.2	19.1	65.768	-19.3	19.5	99.15	11

C41/C42 REVERSE BLANK

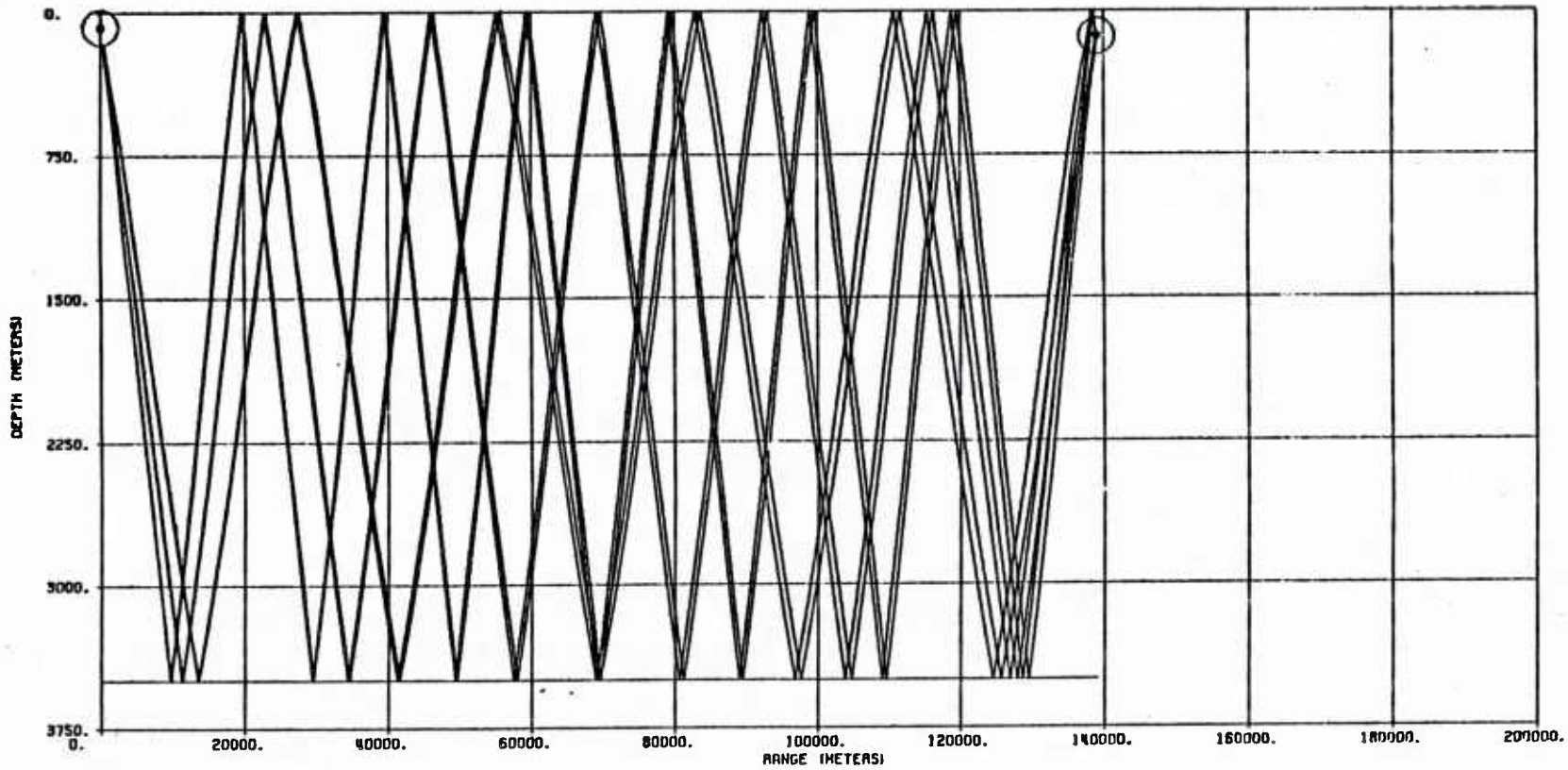
RANGE = 75 MILES

REVERSE BLANK

E11MAR35 RIDGE



ANGLE,DELAY MAX=-109.08 DB
ANGLE MAX=-104.89 DB
DELAY MAX=-102.65 DB
DESIRED RANGE= 74.9NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=15.0DEGREES

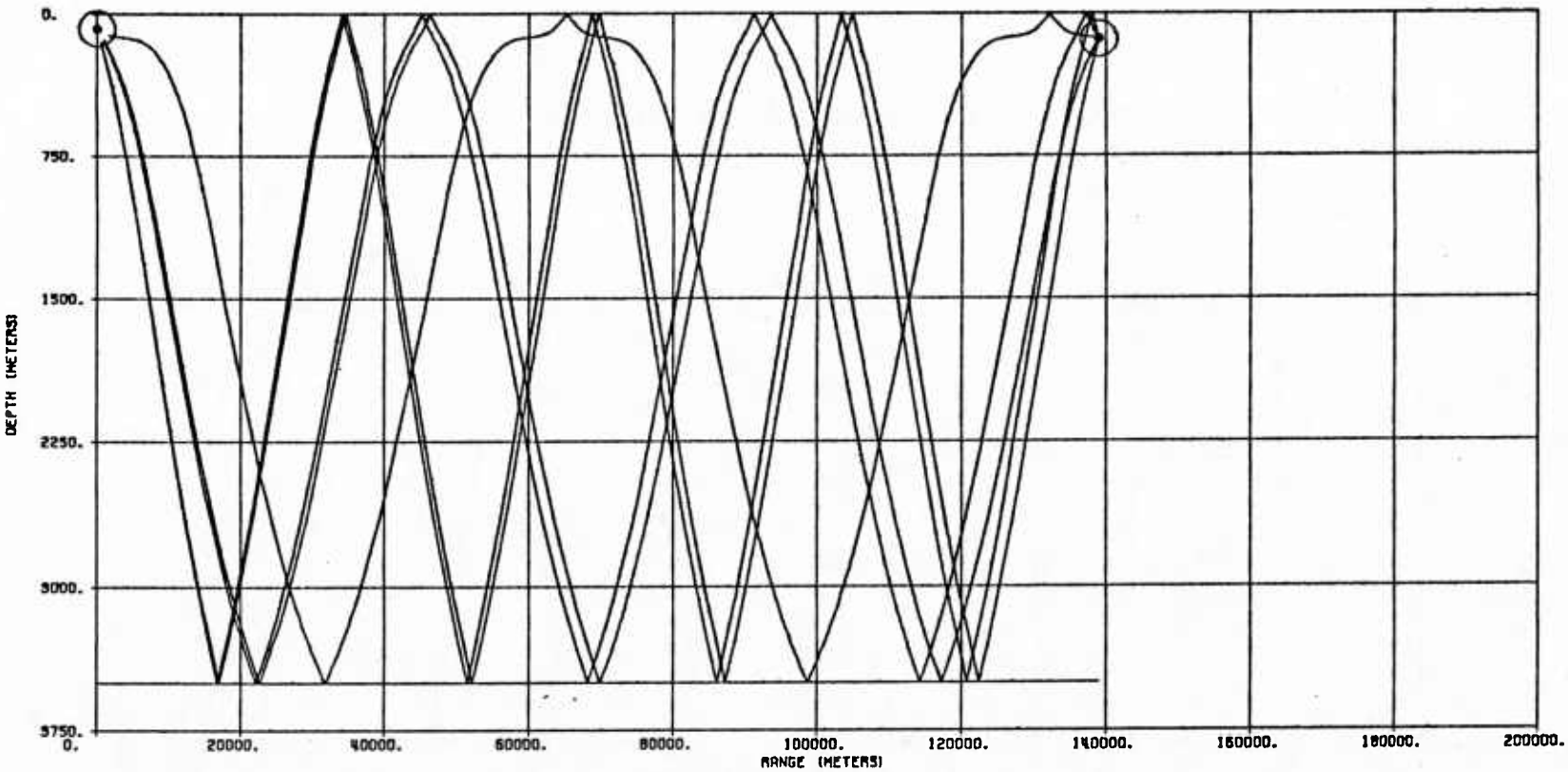


RUN FOR BT52C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
11.5	-11.3	95.060	-11.8	12.1	101.39	9
11.6	11.5	95.096	-11.9	12.3	101.44	10
14.6	-14.5	96.300	-14.8	15.1	102.03	11
14.7	14.6	96.345	-15.0	15.2	102.06	12
17.5	-17.4	97.742	-17.7	17.9	102.46	13
17.7	17.6	97.796	-17.8	18.1	102.48	14

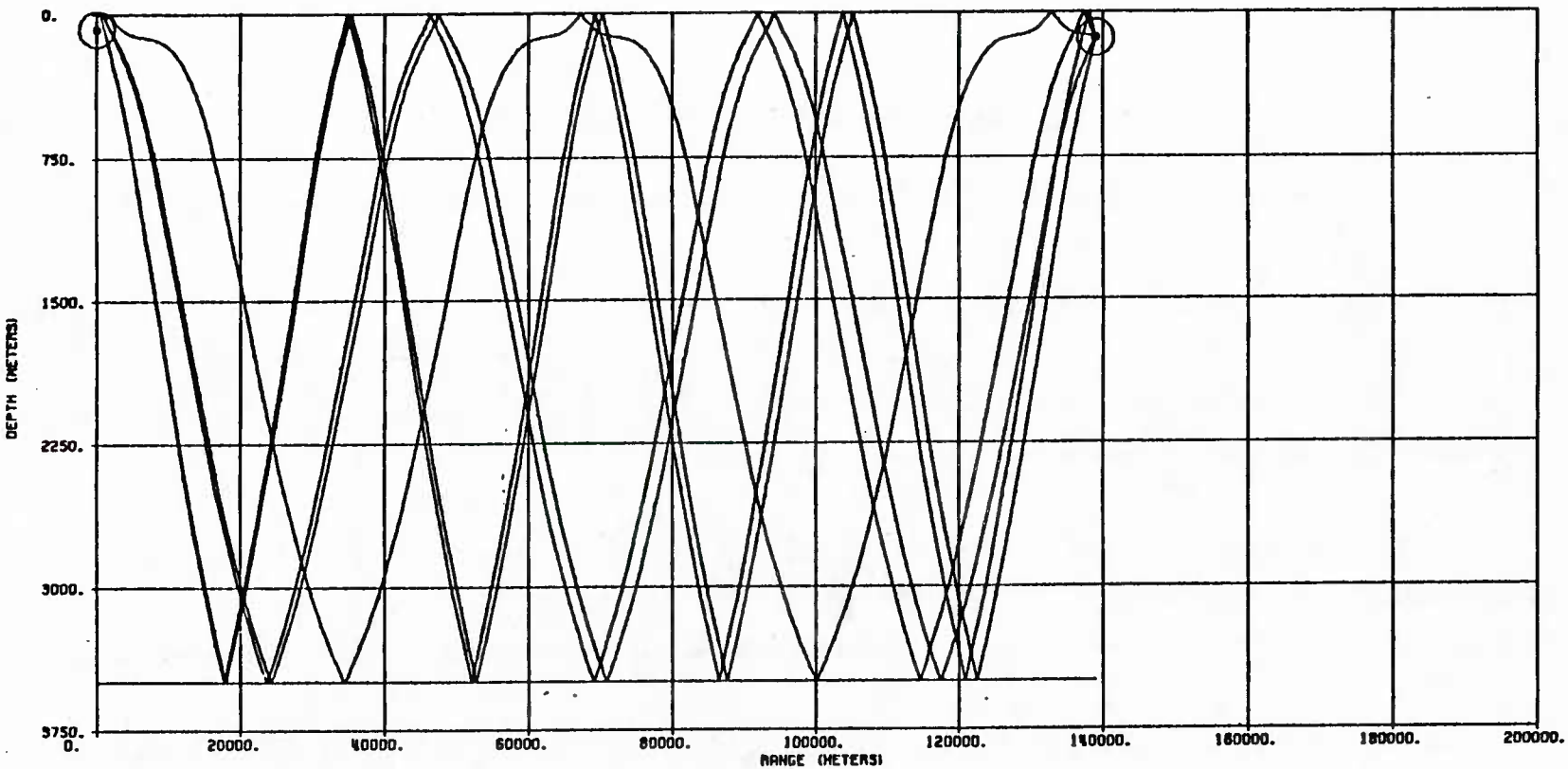


RUN FOR BT52C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
1.9	0.6	92.516	-3.2	4.4	108.50	4
4.2	-3.8	93.196	-4.8	5.7	97.77	5
4.5	4.1	93.210	-5.2	5.9	98.26	6
8.1	-7.9	94.027	-8.5	9.0	100.28	7
8.3	8.1	94.053	-8.7	9.1	100.40	8

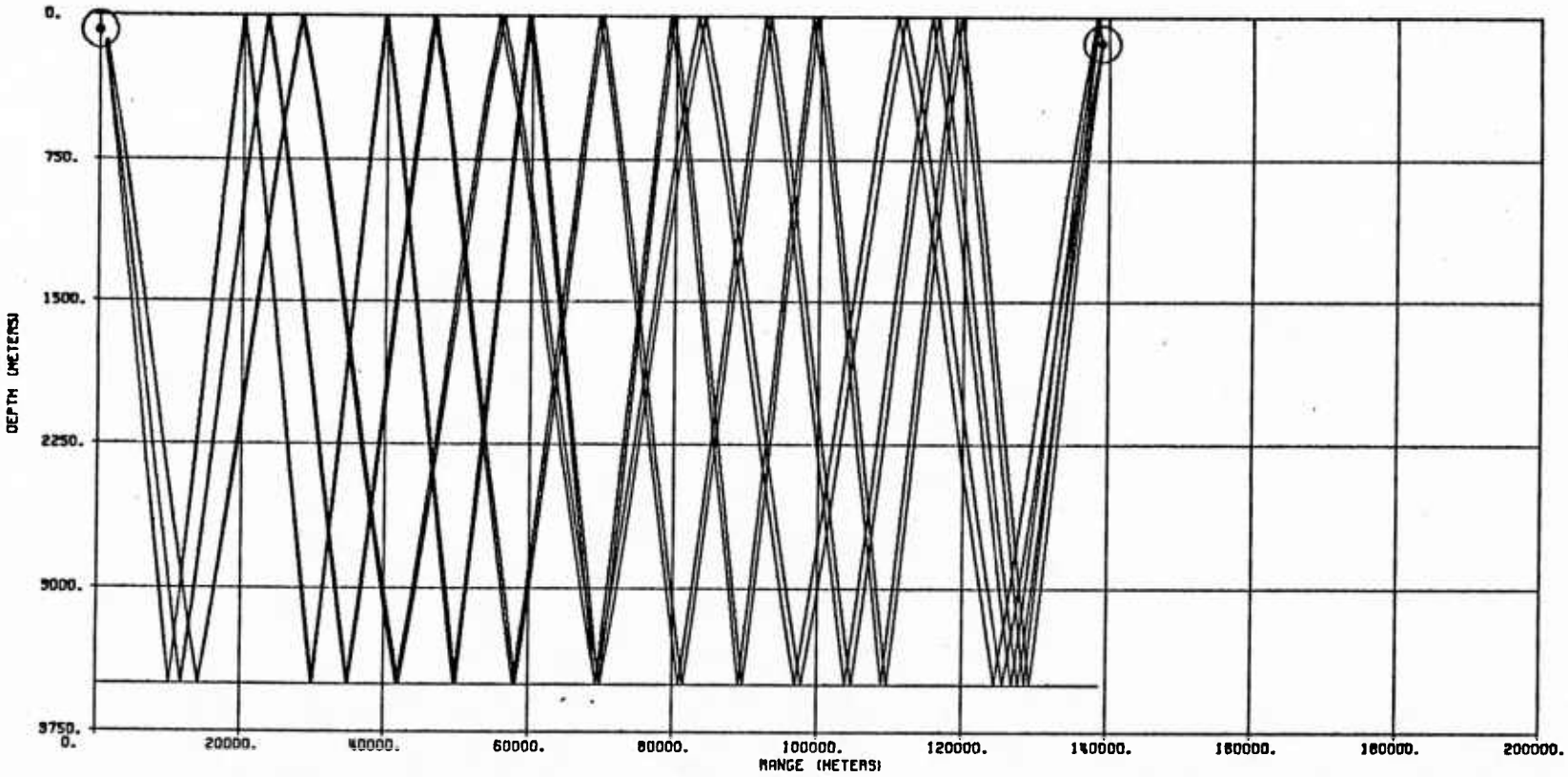


RUN FOR BT52C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.0	0.7	92.521	-3.2	4.4	102.44	5
-4.4	-3.9	93.205	-5.1	5.8	98.02	6
-4.6	4.3	93.219	-5.3	6.1	98.45	7
-8.2	-8.0	94.042	-8.6	9.1	100.35	8
-8.4	8.2	94.068	-8.8	9.2	100.48	9



RUN FOR BT52C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-11.6	-11.4	95.081	-11.9	12.2	101.43	10
-11.7	11.6	95.117	-12.0	12.4	101.47	11
-14.7	-14.6	96.326	-14.9	15.2	102.05	12
-14.8	14.7	96.372	-15.0	15.3	102.08	13
-17.6	-17.5	97.773	-17.8	18.0	102.47	14
-17.7	17.6	97.828	-17.9	18.1	102.49	15

C49/C50 REVERSE BLANK

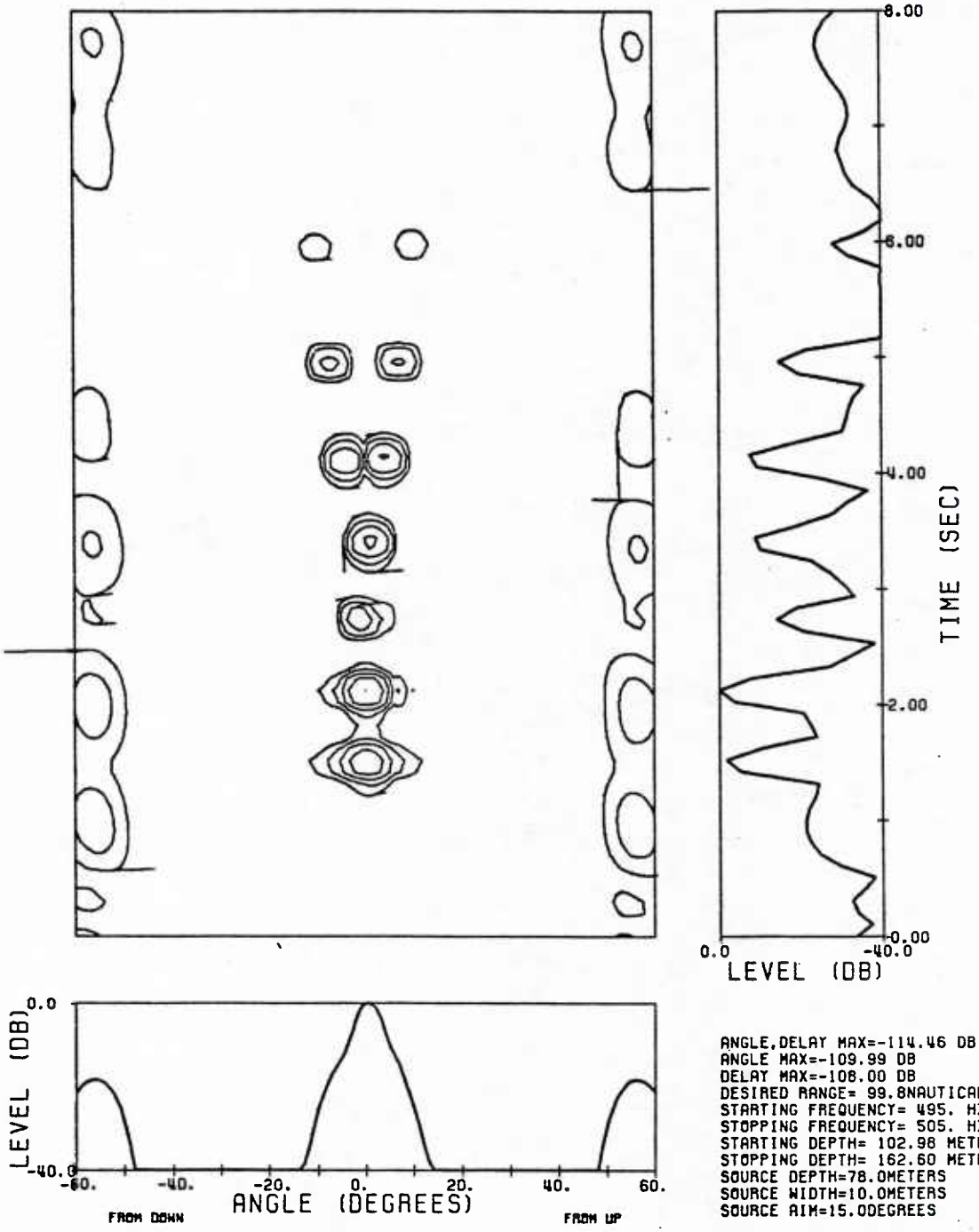
TM No. 811061

RANGE = 100 MILES

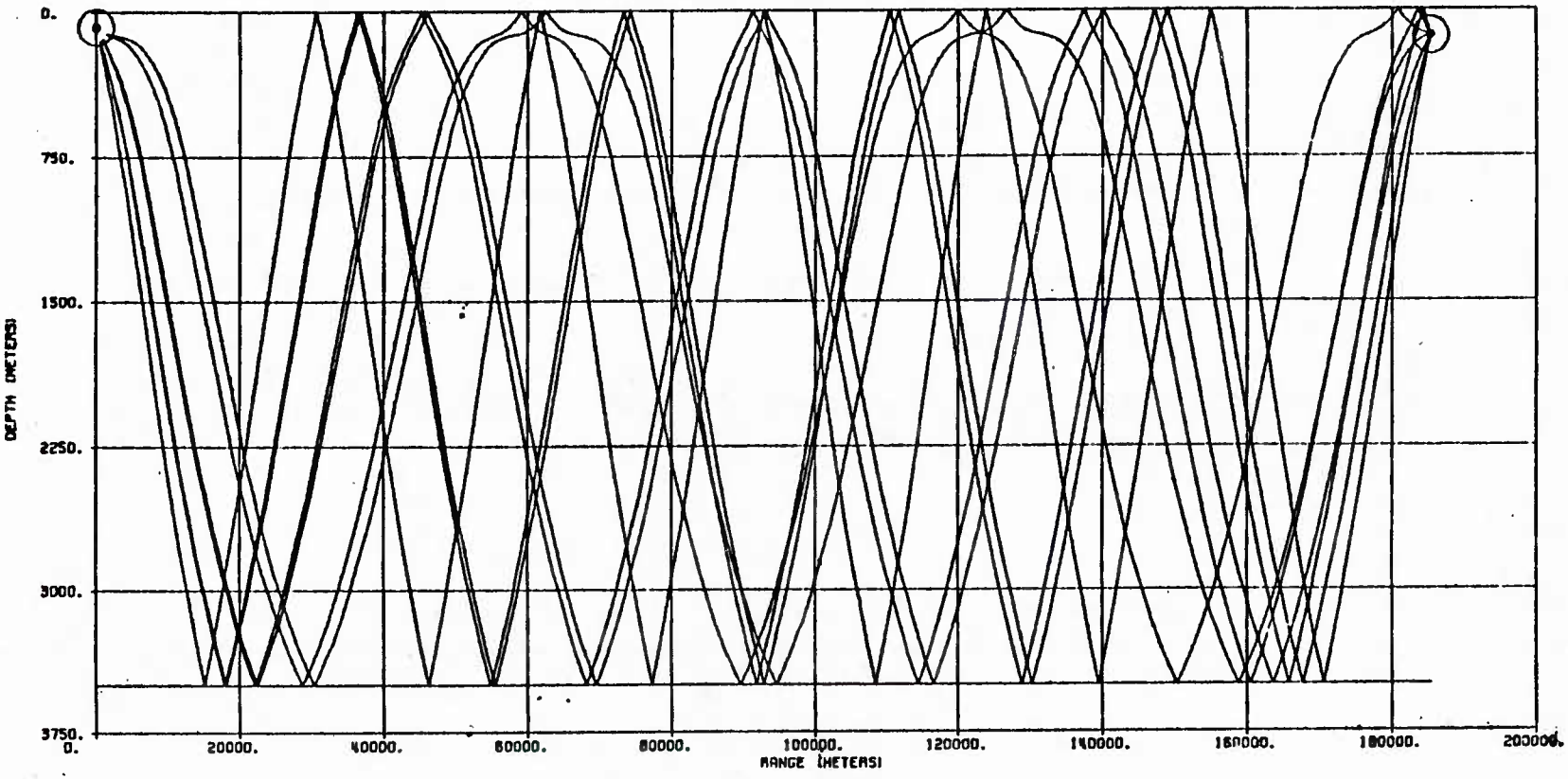
REVERSE BLANK

TM No. 811061

E11MAR35 RIDGE



ANGLE,DELAY MAX=-114.46 DB
ANGLE MAX=-109.99 DB
DELAY MAX=-108.00 DB
DESIRED RANGE= 99.8NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=15.00EGREES

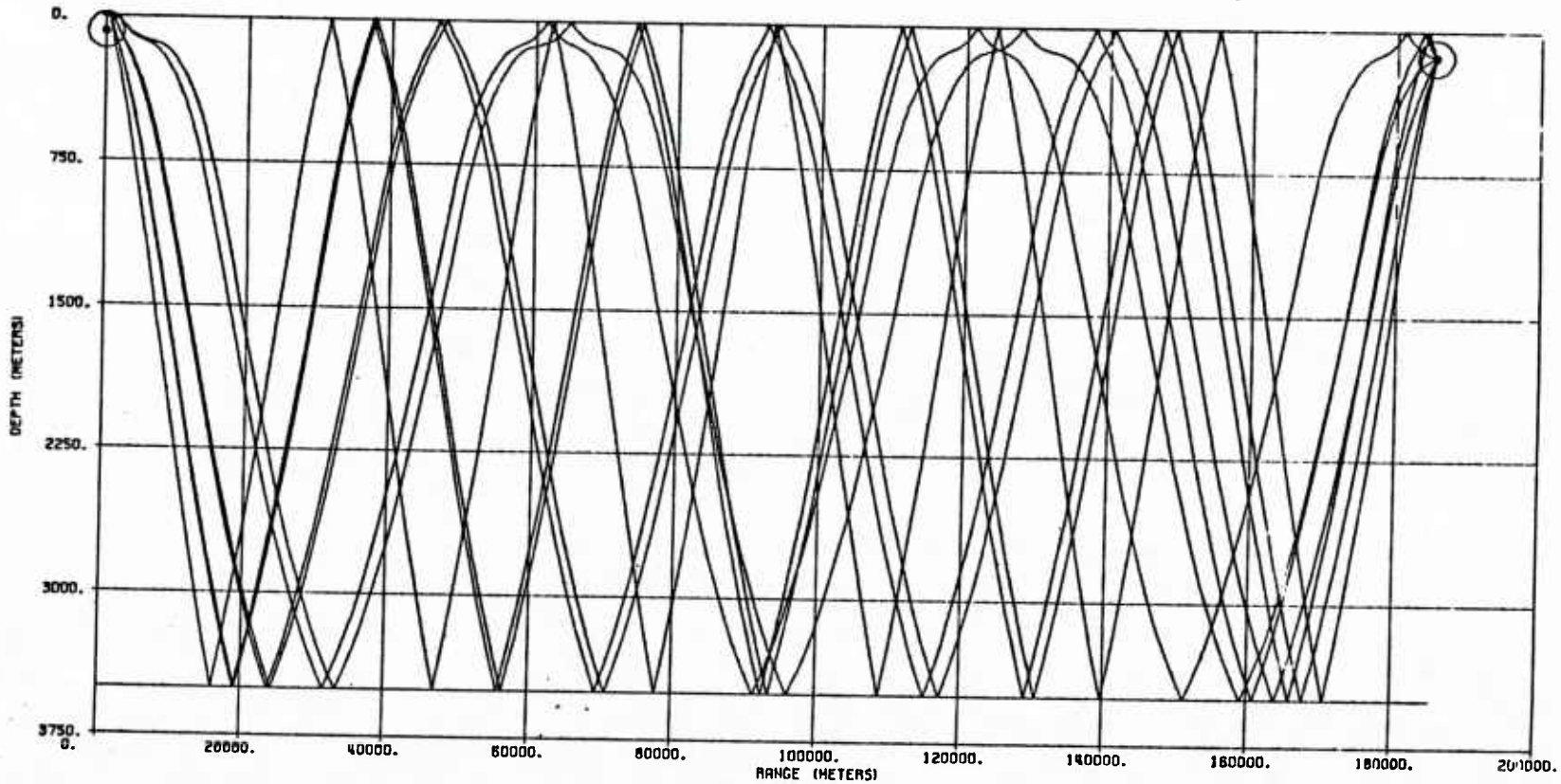


RUN FOR BT51C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 185930.96 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.0	-0.7	123.571	-3.2	4.4	104.27	5
2.1	1.0	123.577	-3.3	4.4	100.82	6
4.2	-3.8	124.266	-5.0	5.8	100.37	7
4.5	4.1	124.279	-5.2	5.9	100.72	8
7.2	-7.0	125.074	-7.6	8.2	102.39	9
7.4	7.1	125.087	-7.8	8.3	102.51	10
9.9	-8.7	126.032	-10.2	10.6	103.44	11



RUN FOR BT51C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 185330.96 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.0	-0.8	123.576	-9.3	4.4	100.66	6
-2.1	1.1	123.582	-9.3	4.4	99.86	7
-4.4	-4.0	124.274	-5.1	5.9	100.54	8
-4.6	4.2	124.288	-5.3	6.0	100.84	9
-7.3	-7.1	125.088	-7.7	8.3	102.45	10
-7.4	7.2	125.111	-7.9	8.4	102.56	11
-9.9	-9.8	126.050	-10.3	10.7	103.47	12

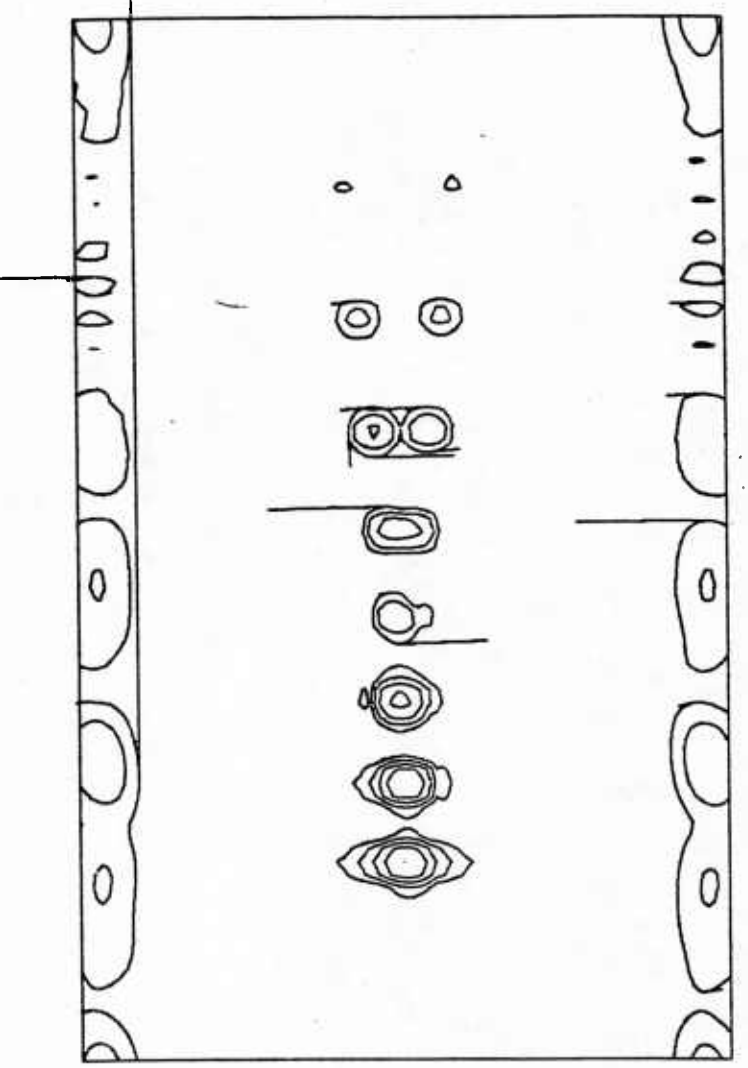
C55/C56 REVERSE BLANK

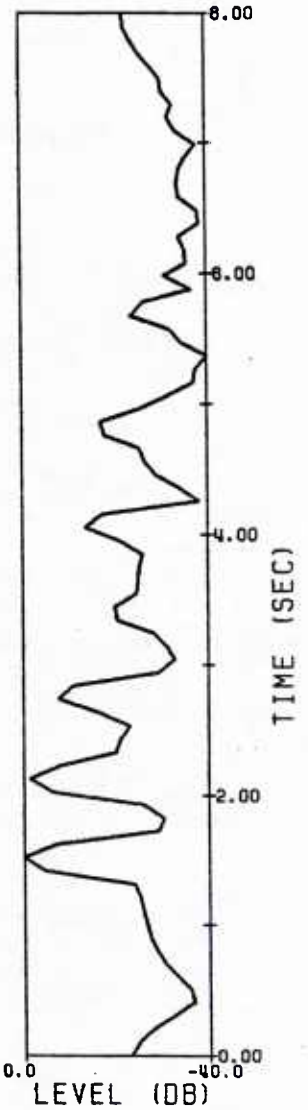
RANGE = 117 MILES

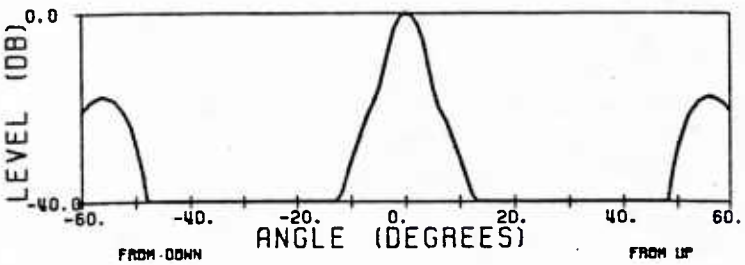
REVERSE BLANK

TM No. 811061

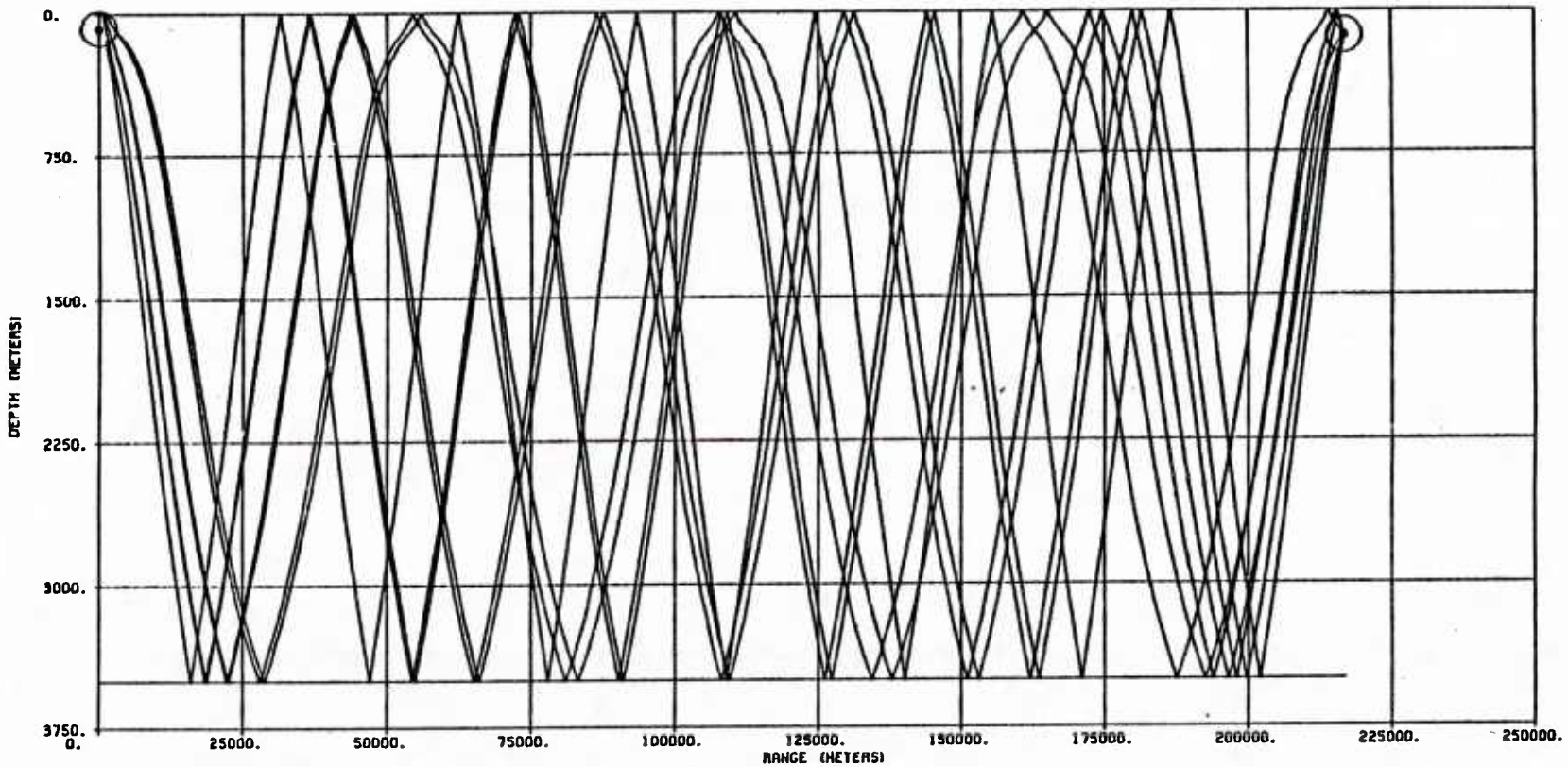
E11MAR35 RIDGE







ANGLE,DELAY MAX=-117.62 DB
ANGLE MAX=-112.77 DB
DELAY MAX=-111.03 DB
DESIRED RANGE= 117.0NAUTICAL MILES
STARTING FREQUENCY= 495. HZ.
STOPPING FREQUENCY= 505. HZ.
STARTING DEPTH= 102.98 METERS
STOPPING DEPTH= 162.60 METERS
SOURCE DEPTH=78.0METERS
SOURCE WIDTH=10.0METERS
SOURCE AIM=15.00EGREES

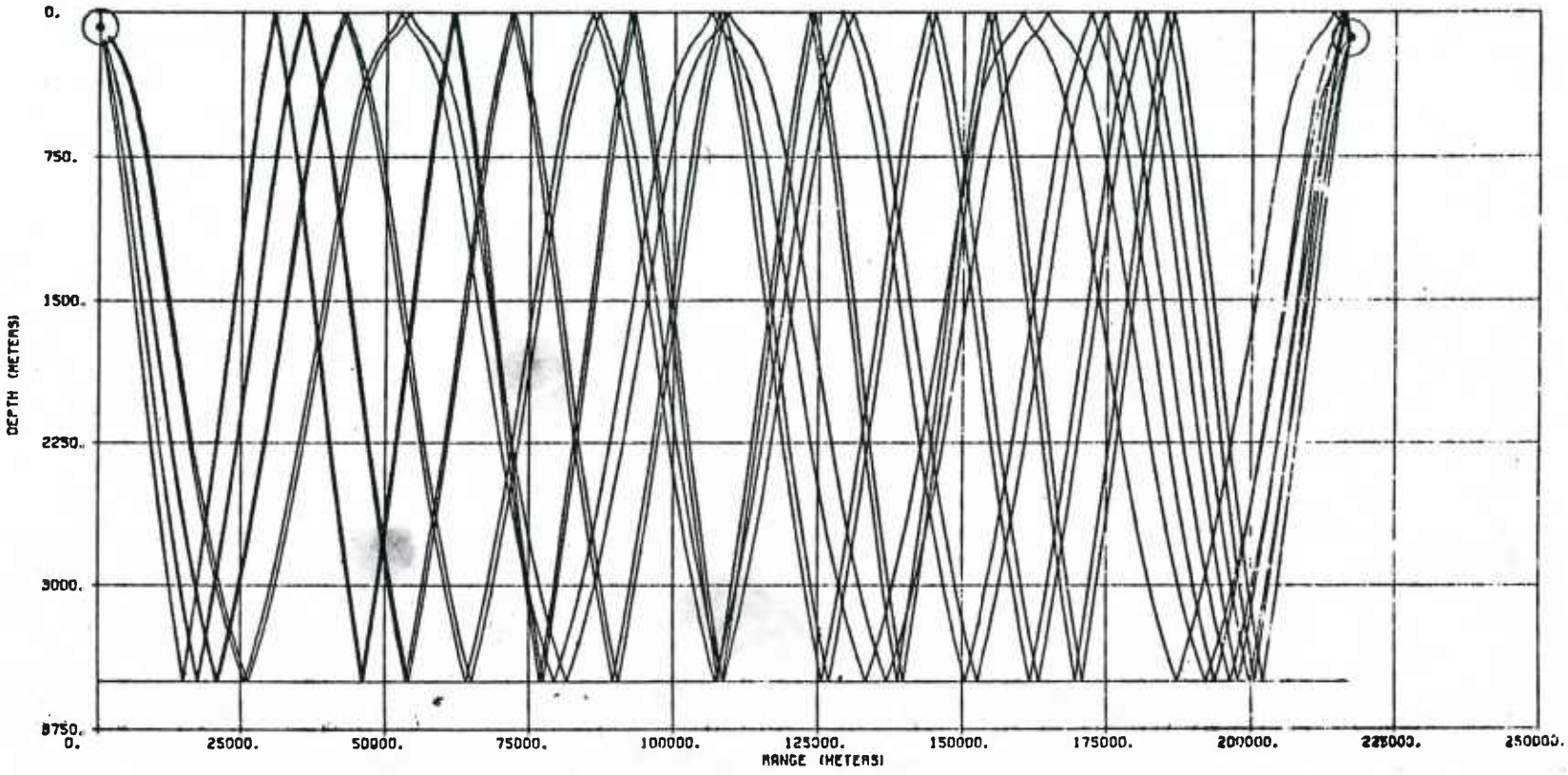


RUN FOR BT50C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 216837.23 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.7	-2.0	144.915	-3.7	4.7	100.38	8
-2.9	2.3	144.924	-3.9	4.9	100.76	9
-5.2	-4.9	145.645	-5.8	6.5	102.57	10
-5.4	5.0	145.662	-6.0	6.6	102.77	11
-7.6	-7.4	146.488	-8.1	8.6	104.00	12
-7.8	7.6	146.512	-8.2	8.7	104.06	13
-9.9	-9.7	147.459	-10.2	10.6	104.83	14



RUN FOR BT50C

SOURCE DEPTH = 78.00 METERS
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS
TARGET RANGE = 216837.23 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.6	-1.8	144.909	-3.7	4.7	100.18	7
2.8	2.1	144.918	-3.8	4.8	100.67	8
5.1	-4.8	145.636	-5.7	6.4	102.45	9
5.3	4.9	145.652	-5.9	6.6	102.66	10
7.6	-7.9	146.474	-8.0	8.5	103.93	11
7.7	7.5	146.498	-8.1	8.6	104.05	12
9.8	-9.7	147.441	-10.2	10.6	104.80	13
9.9	9.8	147.472	-10.3	10.7	104.86	14

C61/C62 REVERSE BLANK

A COMPARISON OF MULTIPATH ARRIVAL STRUCTUES OBSERVED IN THE PRESENCE OF SURFACE DUCT WITH PREDICTIONS OBTAINED USING CLASSICAL RAY TECHNIQUES AND THE PARABOLIC EQUATIONS METHOD

Herbert A. Freese
Formally Of The Submarine Sonar Department

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